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1931—1932.

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A Member shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

An Honorary Member shall be a person of acknowledged eminence in some branch of water supply or of engineering.

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An Associate shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

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The initiation fees and annual dues are as follows:

	Initiation Fees		*Annual Dues*
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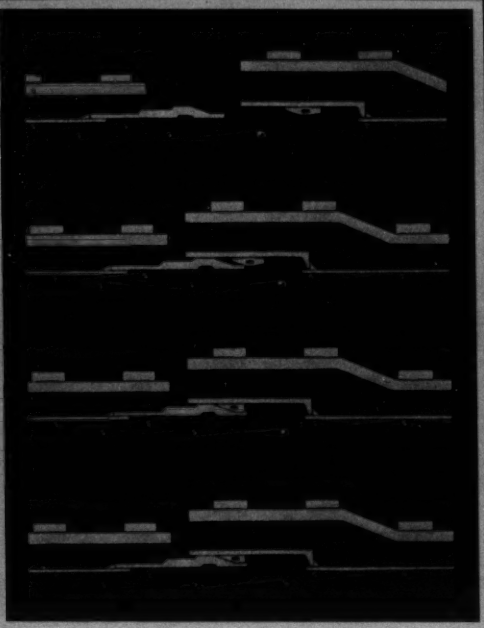
This Association has six regular meetings each year, all of which, except the annual convention in September, are held at Boston.



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CHLORINATION FOR SPECIAL AND EMERGENCY PURPOSES.

BY J. D. MACMAHON.*

[*Read September 30, 1931.*]

It is a well established fact that adequate chlorination of water supplies is a definite safeguard to Public Health. The phenomenal decline in the typhoid-fever death rate in North America and Europe since the beginning of the 20th century must be attributed largely to the increased use of chlorination together with advances in methods for its application.

This situation has been ably reviewed by Wolman and Gorman† from a statistical angle. The data presented by them reveal the fact that although the typhoid-fever death rate has declined to, roughly, one-tenth of that recorded in 1900, there is no justification for assuming an attitude of entire satisfaction towards existing conditions. To establish their case, Wolman and Gorman have presented facts and figures to expose the gaps that exist even now in our lines of defense. When these are penetrated, other water-borne epidemics are added to the records.

Many large typhoid outbreaks have occurred during the last decade. Analysis of the causes has lead to the disquieting discovery that "over three-quarters of the waterborne illness reported in the United States during the decade 1920–1929, representing 40 per cent. of the outbreaks, was due primarily not to pollution of the raw water at its source but to defects in the system for collecting, treating, storing or distributing the water for public consumption."

Liquid chlorine, dispensed by means of suitably designed equipment, is used most widely for the disinfecting of water supplies. Chlorine in this form has done a commendable job and will undoubtedly continue to bear the brunt of the responsibility of protecting public water supplies. Nevertheless there has been a need for a dependable ally that could be applied readily for special and emergency purposes without necessitating the use of elaborate dispensing equipment.

Oldest among the possible allies is chlorinated lime or bleaching powder, but it has the fundamental shortcoming of being relatively un-

*Of Mathieson Alkali Works, Niagara Falls, N. Y.
†*Am. Jour. Pub. Health*, Vol. 21, 1931, p. 115.

stable. Solutions of hypochlorites, too, are not satisfactory because they lack stability and present a problem of transportation.

A new and improved chlorine carrier in solid form was placed on the market in 1928. The active element of this product is a true calcium hypochlorite, having the chemical formula $Ca(OCl)_2$. Chlorinated lime or bleach is generally called calcium hypochlorite but is in reality, calcium oxychloride, $CaOCl_2$. Only one of the chlorine atoms in chlorinated lime is in the "available" form; in true calcium hypochlorite both are active. This fact accounts for the higher "available chlorine" content of the latter. The following representative analysis of this product and of high-grade chlorinated lime will best present the distinction between the two chemicals:

	Calcium Hypochlorite. Per cent.	Chlorinated Lime. Per cent.
Available Chlorine	63.0	35.0
Calcium Chloride	0.5	29.5
Calcium Hydroxide	3.0	13.0
Inert and insoluble matter (Including Calcium Carbonate)	1.0	6.5
Sodium Chloride	31.5	None
Water	1.0	16.0

The high available chlorine content of hypochlorite is an important factor in facilitating the distribution and handling of this chemical.

The extremely low value of calcium hydroxide and inert insoluble matter in calcium hypochlorite allows the active element to dissolve rapidly and completely even in cold water and produces a minimum amount of sludge. Reducing the calcium chloride content to a negligible quantity has eliminated undesirable hygroscopic tendencies, permitting the powder to retain its free-flowing state, even when exposed to normal atmospheric moisture for an extended period of time. Another outstanding factor is the remarkable degree of stability displayed under all conditions of storage. Summer heat, the enemy of other hypochlorite chlorine carriers, has little effect on the stability of this product. It will lose not more than 1½ per cent. of its content of available chlorine when exposed to a storage temperature of 90° F. for a period of one month.

The process of manufacture of calcium hypochlorite is such that a material of uniform quality can be produced regardless of climatic conditions. This eliminates a situation that has been a source of trouble in the past to both producer and consumer, due to the poor quality of the chlorinated lime manufactured during the hot and humid atmospheric conditions that prevail during the summer.

Calcium hypochlorite was quickly recognized as an excellent means for providing "available chlorine" for emergency purposes, or to supplement the work of existing chlorinating equipment. Application of this new product can take the place of other chlorine equipment in case of a

forced shutdown. It can also be dispatched to any point in the water-supply system where it may be needed to protect against pollution that is periodic in nature, or so small or so located as to render impractical the installing of regular chlorinating equipment.

Metropolitan District of Boston.

The Metropolitan District Commission of Boston is one of the large water-works organizations to press calcium hypochlorite into this kind of service. At the gatehouse of Weston Reservoir chlorine is applied continually. Operation of the chlorinators employed requires the use of a motor-driven water pump. Calcium hypochlorite is used, therefore, as a stand-by to pick up the disinfecting treatment should the power supply be interrupted and the chlorinators placed temporarily out of commission.

The equipment consists of two tanks each of approximately 250-gal. capacity, constructed of 2-in. pine board, and provided with 1-in. outlet valves located at the bottom of each tank. Two hundred gallons of water are stored at all times in these tanks, and an adequate supply of calcium hypochlorite is maintained in drums alongside. When the emergency occurs, a sufficient quantity of hypochlorite is added to one tank to care for the chlorine demand for one hour. The resulting hypochlorite solution is then fed to the water supply at a rate that will lower the level in the tank one inch every two minutes; this rate of discharge maintains the required chlorine dosage. The tank discharges completely in one hour. If the interruption of power supply extends over a longer period, the second tank is prepared and used. The amount of calcium hypochlorite added to each tank depends upon the existing draft from the reservoir. Under average conditions the amount is sufficient to produce a hypochlorite solution having an available chlorine content of about one per cent. Interruption in the power supply has required the employment of this auxiliary chlorination equipment from time to time.

The equipment is inexpensive. It can remain idle for protracted periods of time and still be depended upon to function properly in case of necessity. The stock of hypochlorite will withstand prolonged storage without undergoing much deterioration. Finally, its high rate of solubility will permit a batch of hypochlorite to be prepared to full strength in a few minutes' time.

In times of high water and unusual rainfall, hypochlorite is also used at scattered points in the Metropolitan Water System to disinfect the small streams which are tributary to reservoirs. This is a precautionary measure to insure the elimination of contamination that might come from the barns or stables of farms on the catchment areas of these streams. No particular effort is made to maintain a minimum dosage since the volume of water treated is small as compared with that of the reservoirs into which these streams flow.

An illustration of how calcium hypochlorite can be used to advantage in eliminating a continual threat of pollution also exists in this water-supply system. The sewage-treatment plant of Regis College at Weston was found to be inadequate. Some of the effluent from the septic tanks reached the diversion ditches on the watershed of Weston Reservoir. Since the ditches may overflow and their waters reach the reservoir, precautionary measures were deemed advisable, and the college authorities were instructed to remedy the condition.

Since an adequate sewage-treatment plant would have cost about $30 000, the Commission suggested chlorination of the effluent from the septic tanks. This is being done by the simple expedient of dissolving calcium hypochlorite in a barrel coated with pitch on the inner surface and dispensing the resulting solution through a small glass tube at a rate that will maintain a dosage more than sufficient to disinfect the effluent.

Small Municipal Water Supplies.

The statistics presented by Wolman and Gorman* reveal that 64.9 per cent. of the typhoid-fever and dysentery outbreaks in the United States, and 77.5 per cent. of those in Canada, during the years 1920–1929 have occurred in towns having a population of 5 000 or less. Whatever the causes, it seems to follow that the smaller municipalities would do well to give more careful consideration to proper chlorination of their water supplies.

The village of Lewiston, New York, has solved its problem of disinfection by using hypochlorite. This community has a population of approximately 800, and draws its water from the Niagara River at a point about seven miles below the city of Niagara Falls. The average daily draft is approximately 80 000 gal.; during the summer months this average is exceeded by approximately 25 per cent. The water is dosed with ½ to 2½ grains of alum per gallon, depending upon seasonal conditions; detained for about an hour in a 30 000-gal. settling tank; passed through two small, rapid sand-filters into a 6 000-gal. clear-water well; and finally pumped into the mains on which a 100 000-gal. distributing reservoir rides.

The chlorinating equipment consists of two 250-gal. concrete tanks which are piped, about 2 in. from the bottom, to a small cast-iron porcelain-lined orifice box. The latter is standard in design and is equipped with a float which actuates a valve to control the level of the hypochlorite solution entering from the stock tanks. The solution is fed from the orifice box into the water stream by means of a needle valve which is equipped with an indicator showing the degree of opening of the valve and consequently the rate at which the solution is discharged. The stock solution is prepared by dissolving two pounds of hypochlorite in 250 gallons of water. This produces a solution with 600 p.p.m. of available chlorine constituting an 18-hour supply at peak demand. Because of the small amount of in-

*loc. cit.

soluble material, this solution requires no preliminary settling. It is conveyed to the orifice box through 1-in. galvanized-iron piping, equipped with brass gate valves allowing the tanks to be operated independently.

The hypochlorite solution is added to the water between the settling tank and the filters. It is regulated so as to give a chlorine concentration of not less than 0.2 p.p.m. on top of the filters. Experience has shown that this will leave a safe residual after the water has passed through the filters. At the present time, two pounds of hypochlorite are being added to 200 000 gal. of water and reduce a 48-hour raw-water gelatine count from 15 000–16 000 per cc. to a filtered water count of 50–60 per cc. with negative *B. coli* test count. Chlorination previous to the filtering operation necessitates a dosage approximately twice that required when it is applied to the filtered water.

The chlorination equipment described has been in continuous operation for 16 years, with only occasional replacement of the iron piping between the stock tanks and the orifice box. Its cost of installation was about $300, and the upkeep has been negligible. Chlorinated lime was used until 1930, when hypochlorite was substituted. This resulted in material improvement in performance featuring the following advantages:

1. Greater solubility facilitates preparation of stock solutions.
2. Uniformity of available chlorine content insures preparation of stock solutions of uniform concentration.
3. Lower content of insoluble matter removes the necessity for settling the stock solution.
4. The sludge from chlorinated lime would clog the regulating valve of the orifice box, resulting in erratic dispensing and necessitating frequent cleaning. This trouble has now vanished.
5. The higher ratio of available chlorine to calcium (approximately four times that of chlorinated lime) has resulted in a material reduction of the hardness introduced by the chlorination.
6. The greater stability of hypochlorite and its higher available chlorine content has reduced the storage problem.

Another interesting development in the use of hypochlorite is the use of a machine called the "Mixitt" for dispensing hypochlorite solution to water. This equipment may be installed in a pipe. Flow through the pipe operates a paddle wheel connected to a reciprocating piston which ejects water from the pipe in amounts varying with the rate at which hypochlorite solution is to be introduced. The water so by-passed enters the bottom of a tank containing white oil. This oil is displaced into a second tank containing the hypochlorite solution. The oil, being of lower specific gravity, acts as a piston and forces an equivalent volume of hypochlorite solution into the water system. The re-agent tank is made slightly larger than the oil tank to avoid the possibility of getting oil into the water supply. By this means, the correct amount of hypochlorite may be automatically fed into the water supply regardless of variation in rate of flow or in pipe pressure.

The first installation of this kind was made in Villesca, Iowa, for a small plant designed by Colonel H. A. Allen of Chicago. The hypochlorite solution is prepared from high-test hypochlorite, and the re-agent tank is large enough to hold one week's supply. Since the dispensing equipment is entirely automatic in operation, the only attention required is the periodic refilling of the solution tank. The plant at Villesca runs without attention other than a weekly visit. Space will not allow a more detailed description of this equipment. It was developed by Max B. Miller & Company of New York, N. Y.

Disinfection of Water Mains.

The disinfection of water mains after construction, before placing them in service, is recognized as an important safeguard against pollution of the water supply. The pipe is exposed to contamination from the time it leaves the foundry until it is in place and ready to carry water. To eliminate the effects of pollution from new mains requires not only thorough mechanical cleaning of the inner surface of the pipe, but also chlorination. Hypochlorite is widely used for the latter purpose. In many cases it is applied by placing a predetermined amount of the powder in the pipe line at regular intervals during the process of construction. Hypochlorite lends itself well to this purpose. On account of its high degree of stability, it can remain exposed in the pipe for an extended period of time without suffering noticeable deterioration. Its ready solubility permits it to give up rapidly its available chlorine when the water is turned into the line, and its high concentration of available chlorine reduces the amount of material to be handled.

This use of hypochlorite is well defined in an order issued by the Engineering Division of the Water Department of Houston, Texas, to all inspectors on water-main construction. The dosage of hypochlorite advocated for different pipe sizes is as follows:

Size of Pipe. (Inches.)	Interval of Dose. (Linear feet.)	Calcium Hypochlorite Powder. (Ounces per dose.)
6	128	11
8	96	13
10	64	13
12	48	13
16*	32	13
16	36	16
20	24	16
24	24	24
30	24	43

*Up to this point the pipe lengths are 16 feet; they drop to 12-foot lengths on the larger sizes.

By this schedule the dosage is regulated to give substantially the same concentration of available chlorine for all pipe sizes. The initial concentration is approximately 250 p.p.m. While this dosage is extremely high, it

indicates the importance attached to insuring that disinfection be complete before a newly-constructed main becomes part of the distributing system. It has been common practice elsewhere to use not more than ten per cent. of the dosage indicated in the preceding tabulation. Good results have been obtained, but it is safer to overdose in order to care for possible conditions of extreme contamination.

A method of placing the powder is indicated by the following quotation from the Houston instructions:

> The placement of the powder-like substance in the pipe is the duty of the contractor, but the inspector shall supervise the placing of each dose. The inspector must indicate on his profile by the use of a symbol, the approximate location of each dose . . . . The method of sterilization after the calcium hypochlorite has been placed in the main and two valves are available and with at least one fire hydrant between these control valves, will be to allow the water to slowly enter the main from one direction and displace the air, after which the fire hydrant and the control valves will remain closed for at least one hour. This sterilization will be done in the presence of an authorized representative of the Sanitation Section of the Engineering Division.
>
> Hypochlorite can be used in the same manner, when breaks in pipe lines are being repaired or under any other conditions which may allow bacterial contamination to enter the distributing system.

Control of Algæ.

Hypochlorite is being used extensively and effectively either to remove algæ growths, or to create a condition that will inhibit the formation of such growths. The value of hypochlorite in removing and subsequently inhibiting the accumulation of algæ growths in water reservoirs is demonstrated by the experience of the water department of Wilmington, Del. Subsequent to the regular chlorination the water passes through a 35-m.g. reservoir and a 500 000-gal. stand-by reservoir. Storage resulted in an undesirable accumulation of slime in these reservoirs during the summer months. In 1930, hypochlorite was, therefore, sprinkled on the surface of the water along the periphery of the reservoirs where slime growths occurred most abundantly. Chlorination of the main body of the larger reservoir was accomplished by distributing the powder from a boat. Hypochlorite was added in sufficient quantity to give, at the time of application, a dosage of 0.25 p.p.m. available chlorine. This was enough to maintain a residual at the outlet of the reservoir of 0.08 p.p.m. The powder dissolving as it sank distributed chlorine throughout the depth of water. Localization of the chlorination was thus avoided. The amount and frequency of dosage for such treatment depends upon the severity of the condition to be corrected and is strictly a local problem.

During the Summer of 1930, the aqueduct from the Weston Reservoir of the Boston water-supply system accumulated an excessive amount of

"pipe moss." At times this growth broke away from the walls of the aqueduct, making it necessary to clean the screens at the terminal chamber three or four times a day.

The Metropolitan District Commission used hypochlorite to relieve this condition, applying it in two doses, each of approximately twenty hours' duration and a month apart. The aqueduct is slightly over a mile in length and carried, at that time, a flow of 100 m.g.d. The dosage was varied from 0.3 p.p.m. available chlorine to 0.56 p.p.m. The displacement of water in the aqueduct was approximately one hour, and a trace of available chlorine was indicated at the terminal, the highest dosage showing a residual of 0.14 p.p.m. at this point.

The first indication of the effectiveness of chlorination was an unusual accumulation of slime on the screens, due to the dislodging of pipe growths from the aqueduct walls. After the treatment, the daily accumulation of slime was considerably reduced and the screens required not more than one cleaning per day. One month later, it was again found necessary to clean the screens more frequently, and the same treatment was repeated. This was sufficiently effective to last until the advent of colder weather when no trouble of this nature is normally experienced.

For this treatment the calcium hypochlorite was applied as a solution which was prepared in a barrel and dispensed into the fore bay at the entrance to the aqueduct by means of a header, to obtain quick distribution throughout the mass of the water.

Algæ may accumulate at times on the surface of rapid sand-filters. The resulting slime layer clogs the bed and increases the head-loss through the filter at a rate greater than normal. More frequent back washing then becomes necessary. The coating of slime, furthermore, decreases the specific gravity of the sand grains, sometimes necessitating a reduced velocity of the wash water to prevent the sand from being carried out of the filter and resulting in ineffective washing.

Hypochlorite has been found to be effective in correcting filter troubles of this type. The usual procedure is to cut the affected filter out of use, leaving about 12 in. of water above the sand surface. Hypochlorite powder is then added to this water at points scattered over the surface of the filter. The chlorinated water is allowed to stand on the filter for at least 30 minutes to allow the calcium hypochlorite to dissolve and diffuse throughout the water. The water level is then pulled down to a point about one inch below the sand surface, where it is allowed to remain from 12 to 24 hours, depending upon the degree of clogging.

This treatment will dislodge the slimy growths which are then readily removed by backwashing. It has been found that 4 lb. of hypochlorite for each 100 sq. ft. of filter surface will produce a sufficiently high concentration of available chlorine to remove even excessive accumulations of algal growths. Treatment such as this will not remove incrustations of aluminum hydroxide. Where these occur in addition to the algal troubles,

hypochlorite treatment should be preceded by the usual alkali treatment. Caustic soda is generally employed at a concentration of approximately 2 per cent.

This attempt to describe some of the interesting developments connected with the application of calcium hypochlorite to water-works problems is as complete as space will permit. It is gratifying to know that all of these applications were originated and developed by water-works men themselves. The valuable properties of calcium hypochlorite and its increasing use have stimulated equipment manufacturers to design apparatus for dispensing it, and it is to be expected that mechanisms for applying chlorine in this form will become available in increasing number and improved design.

DISCUSSION.

HARRY U. FULLER.* It seems to me that the reason why we should pay attention to the cleaning of mains, either new or repaired, is based on the fact that all water utilities are careful to obtain pure water at the source. They either find clean water or purify it for use, by filtration or otherwise, before it is admitted to the distribution system. Thereafter it should be kept as clean during its flow through the pipes as it is when admitted to the pipes.

In past years not enough attention has been paid to this matter. I think that water-works men are becoming increasingly aware of the importance of keeping the water clean after they have once got it in that condition. In Portland, Maine, not many years ago, the chlorination of mains had never been considered. New mains were put into operation, or repairs were made where there were chances for pollution. The joints would be made, the water turned into the line, and by good fortune no trouble was ever experienced.

With the advancing knowledge of these days, Portland is paying more attention to chlorinating its mains. Chlorine has been employed in three forms: as liquid chlorine, hypochlorite in solution and dry hypochlorite. I am glad to hear of the new calcium hypochlorite. It appears that we get per pound of this powder twice as much chlorine as we used to get from chlorinated lime. There is also less sludge.

It has been the practice in Portland to add about an ounce of dry chloride of lime to a length of pipe, particularly in cases where the water pipes were being relaid in trenches in the city streets where sewer pipes might have been broken during construction. A six-mile line of 42- and 48-in. concrete pipe is now nearing completion. The first half of the job is nearly finished and will be ready for testing and chlorinating very shortly. Water will be admitted to the concrete pipe through an 8-in. main at one end of the line. Two 8-in. gates have been installed in the 8-in. line about 20 ft. apart. A small portable chlorinator will control the flow of chlorine

*Chief Engineer, Portland Water District, Portland, Me.

gas through a silver tube to the main between the 8-in. gates. The 8-in. gates will be opened enough to give a somewhat turbulent and rapid flow of water at a known rate, and it is believed that the chlorine will be absorbed by the water before it enters the concrete pipe.

A few years ago it became necessary in a thickly built up street to take out a 6- and put in a 16-in. pipe. A sewer pipe was broken, and considerable sewage discharged into the trench. At that time old-fashioned chloride of lime was used, putting about an ounce to a length of pipe into one end of the line after the line was hooked up. Water was then admitted to the line and left for a day. Afterward the pipe was flushed clean, and our chemist reported that the water was safe. We are intending to get the same report from our chemist before we use the 48-in. line, even if it has to have more than one treatment.

I have noticed that pipe, between the time it arrives on the job and the time it gets into the system, is subject to great possibilities of pollution. In the city of Westbrook, where the 48-in. concrete pipe is being laid, the children play around the job after working hours and are none too careful about what they do inside these large pipes. I am told that there is considerable evidence of pollution and have noticed that in all the larger sizes of pipe these things occur rather often.

I think it behooves all water-works people to keep in mind that they should maintain the purity of the water from the point where they first get it, or make it pure, until it finally comes out of the faucets of the water consumers. Ordinarily we allow the water to stand in the pipes for 24 hours or more before draining it out and admitting fresh water. Then we wait for the chemist to give us a report before we put the line to work. It may be necessary to give it a second dose.

HAROLD W. GRISWOLD.* The Water Bureau of Hartford, Conn., serves about 200 000 people. In disinfecting mains we use either hypochlorite or liquid chlorine from a portable chlorinator. Our choice depends upon the type of job. For short connections to other mains, hypochlorite is the simpler thing to use, as the portable chlorinator requires the existence of at least one corporation cock. For long lines the portable chlorinator sometimes works out to better advantage. When hypochlorite is employed a little bit of sense must be mixed with the chemical. If the pipe line follows a steep grade it is desirable to fill from the bottom and not from the top; otherwise there will be a heavy chlorine concentration at the lowest portion of the line and little disinfectant at the high point. On intersecting lines it is important to flush from every direction. We had one experience in which the line was flushed in one direction only, leaving probably 15 ft. of pipe through which the water did not pass. It is surprising how far that 15 ft. of heavily chlorinated water traveled. There were complaints from many blocks in the vicinity.

One of the towns adjoining Hartford has been putting in a distribution

*Deputy Chief Engineer, Water Bureau, Metropolitan District of Hartford County, Conn.

system, with a total length of about 5½ miles. It had been planned to use hypochlorite to disinfect the pipes, but the feeder line to the town is not complete, and it will probably be four months before the water is turned into the distribution system. The question arises, what will happen to the hypochlorite distributed through those pipes in the four months, and what will be the effect on the lining of the pipes between the time the chemical is put in and the time the water is turned on? The pipe is centrifugally cast iron with cement lining and sprayed coating. I am going to ask Mr. MacMahon what will be the resulting condition.

MR. MACMAHON. I would not anticipate any effect on the lining provided the chemical is not in solution. If it remains a powder its natural tendency in decomposition is to evolve oxygen rather than chlorine. For this reason I do not expect that it would have a bad effect on the lining. The lining is quite resistant to corrosion provided it is not pervious and allows the hypochlorite to get through to the shell of the pipe. The hypochlorite becomes active when wet, so that I believe that much would depend on just how much water got into the pipe.

MR. GRISWOLD. In other words, it would be safer to use liquid chlorine for that particular job?

MR. MACMAHON. Yes. Under the conditions you mention.

W. A. MACKENZIE.* I wonder if you would consider placing the hypochlorite of lime in a container that is soluble in water. Could that be done?

MR. MACMAHON. Hypochlorite can be stored in soluble gelatine containers like a capsule. They call them soluble. I do not know whether or not they would actually dissolve under these conditions; but we have found that the hypochlorite has no effect on the gelatine capsule and the capsule has no appreciable effect on the hypochlorite.

MR. FULLER. Might I ask Mr. Griswold about the sprayed surface of the inside of the pipe, after the cement lining was put on. Could he tell me what the spray was?

MR. GRISWOLD. It is ordinary pipe dip. The reason for spraying is to avoid the preheating necessary when the pipe is dipped. The pipe manufacturers did not care to preheat the cement-lined pipe. Therefore they sprayed the coating onto the pipe.

MR. MACKENZIE. I wonder if you have examined or cut any pipes of this kind, and what the appearance of this lining is?

MR. GRISWOLD. We have not been using such pipes more than about a year. So far as we have examined them they look just the same as they did before they were laid.

SAMUEL H. MACKENZIE.† I wonder if Mr. Griswold could overcome the difficulty with the dry powder if it was placed through a corporation cock when the line is ready to be filled and if that may not be a simple way to apply chlorine when liquid chlorine apparatus is not available.

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*Superintendent of Water Works, Wallingford, Conn.
†Superintendent of Water Works, Southington, Conn.

MR. GRISWOLD. That method would require some sort of blowing equipment.

LINN H. ENSLOW.* May I ask Mr. Fuller what precautions are taken in pre-flushing the line before sterilization, or is the flushing supposed to come afterwards?

MR. FULLER. If we think there is any foreign substance in the line, we flush it thoroughly first. To illustrate: A few months ago we tried putting a thousand feet of 24-in. pipe across tidal mud flats, where it was necessary to work in two or three feet of water even at low tide. We used Universal pipe. In the operation of laying it the crew had to fight the tide every minute. A trench was dug working under water, with the knowledge that there was perhaps one hour in which to put in two or three lengths of pipe. The crew would work frantically, getting the pipe in and hooked up. Then the water would come in over the little mud dikes which had been built, carrying the mud with it, and getting into the pipe to some degree, in spite of the fact that an attempt was made to get a bulkhead over the end of the pipe before the water rushed in. Much mud got into the pipe, as we well knew. At a place very near the low point in the line a blow-off was left. As soon as the line was hooked up, and before it was chlorinated, the water was turned on and run out through the blow-off at the greatest pressure we could get. We ran it first in one direction; then in the other, until the water was clear. Then we repeated the performance. That is an extreme case, but it illustrates the idea that we customarily clean out the pipes first.

In the case of the concrete pipe, previously mentioned, it was all brushed out very carefully. We tried to get all of the polluting matter out of the pipe before the chlorine was admitted to it, because of the knowledge that the chlorine would only work on the outside of the particles, if they were particles of any size, and there might be polluting matter left in the pipe if there were sizable particles of pollution.

*The Chlorine Institute, New York, N. Y.

WATER-WORKS EMERGENCIES FROM THE HEALTH STANDPOINT.

BY WARREN J. SCOTT.*

[*Read September 30, 1931.*]

While new types of emergencies occur from time to time, the vast majority are paralleled by previous experience elsewhere. Discussion of emergencies is helpful, therefore, in that it shows how emergency conditions may be dealt with most effectively.

The causes of some emergency conditions are self evident and the remedies are all important. In other cases, the diagnosis of the trouble is the principal difficulty, after which the remedy may be simple.

In furnishing water to the public, the first duty of the water-works superintendent is to see that the water is safe at all times, and secondly, that a continuous and adequate supply of water is available. When one considers emergencies confronting water-works superintendents, it is natural to think of breaks in pipe lines, breakdowns in pumping equipment or similar misfortunes on the distribution system, but even more serious emergencies have occurred when the quality of the water has been threatened. Under our New England conditions, it is fortunate that most emergencies threatening the safety of our water supplies can be avoided by suitable preparation. However, over a period of a comparatively few years in Connecticut, numerous cases of unpreparedness have occurred.

Inadequacy of Source of Supply.

Perhaps the most serious trouble from the standpoint of the health official has been the inadequacy of sources of public water supply. There are few disasters which menace a community to the extent of a depleted public water supply. It seems almost unnecessary to say that each water supply should be carefully studied from time to time to ascertain that the yield of the sources of supply is sufficient to care for the consumption which may be increasing at a rapid rate. The dry years of 1923, 1924, 1929 and 1930 resulted in the depletion of several public water supplies in Connecticut, and emergency supplies had to be pressed into use. In each case, steps were subsequently taken to increase the available supplies; but with reasonable foresight, the shortages could have been prevented.

On most of our surface water supplies, it is possible to compute safe yields with a knowledge of the local rainfall and from accurate measurements of yield ratios on watersheds with similar characteristics. It is still better for the superintendent under the guidance of competent engineers to keep records of stream flows, water consumption, gains and losses due to storage, etc., on his own particular watersheds so as to make his own yield calcu-

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lations. In many states, the U. S. Geological Survey stands ready to cooperate with local officials in the establishment of gaging stations on water-supply streams. Similarly, in the case of ground-water supplies, accurate pumping tests and ground-water observations will enable a close estimate of the yield of the supplies.

The water-works superintendent is sometimes faced with the situation that he cannot induce his company or his water board to take forward-looking steps to increase his supply. If he is forced to operate on a slender margin of safety in this regard, he should determine what can be done in the case of a shortage due to drought. It may be that he can plan for an emergency connection to some neighboring public water system of ample capacity. There may be some near-by recreational lake free from serious sewage pollution and subject only to contamination from bathers so that an emergency pumping station, a chlorination outfit and a force main to the distribution system may do the trick temporarily. Sometimes a connection can be made with an industrial water supply when suitably treated.

In Connecticut, we have had to make emergency use of various types of temporary water supplies. In each case, the State Department of Health has made a hurried survey of the watershed of the proposed supply and with the coöperation of residents and local health and water officials, has cleaned up dangerous conditions on the immediate watershed. The Connecticut State Department of Health has two emergency chlorinators on hand which have been installed by the department in several shortage emergencies. The department has insisted, however, that the water works borrow or purchase its own chlorinator so as to return the department chlorinators as soon as possible to keep them available for other emergencies, either as a stand-by in case of trouble with the chlorinator on the emergency supply in question or for some other supply.

We have also required the water-works management which makes use of makeshift supplies of poor quality to notify consumers that the water should be boiled for drinking purposes. Notification is to be made by a water-works representative personally or through newspaper announcement or both, depending on the quality of the emergency supply. This is an added safeguard that is usually worth while in case of breakdown of disinfection agencies, even though it may not relieve the water works of legal responsibility. In one case, the local health officer prohibited bathing in a recreational lake within a certain distance of the emergency intake.

Breakdown of Equipment.

Another emergency that frequently arises is the breakdown of equipment used for purification of water supplies. It is unnecessary to say that duplicate chlorination apparatus should be provided in all cases. Chlorinators are delicate machines, and breakdowns cannot be avoided, even with intelligent supervision. The State Department of Health may be called

upon for temporary loan of chlorination equipment when duplicate apparatus fails to function, as may happen. Incidentally, spare chlorinators should be started up occasionally or they may be found wanting when needed.

Filtration plants — especially those of the rapid sand type — may break down for one reason or another. Sufficient storage in the clear well will give some opportunity to make repairs. Spare units should be available, also. By-passes around filter plants are frequently installed for emergency use, but adequate chlorination should be provided if such by-passes are pressed into service.

A peculiar case happened recently in one Connecticut city. The city was drawing water from two supplies — a chlorinated gravity supply and a pumped filtered supply. The first supply suddenly developed a very offensive taste because of algæ, and the whole system was thrown on to the pumped supply. Normally, this pumped supply was used only during the night. Two filter plant operators were available — one for each twelve hour shift. Then one operator developed appendicitis, leaving only one man familiar with the operation of the filter plant. The unpalatable gravity supply had to be used temporarily, but the city succeeded in quickly securing the loan of a trained filter-plant operator from a manufacturer of filter-plant equipment. This action tided them through. They did have to withstand a deluge of complaints, however, until the change could be made.

Odors and Tastes.

There is a growing demand for improvement in the physical characteristics of drinking water, and people are not so ready to put up with objectionable color, taste or odor as they used to be. This is resulting in the installation of an increasing number of rapid sand-filtration plants, both on large and small supplies. In order to cut down on operating costs, designing engineers are laying out rapid sand-filtration plants on small systems which call for little operating attention — perhaps an average of two hours a day or less. These plants are frequently placed in charge of one man, and nobody else in town is familiar with the operation. This is a dangerous plan. The possibility of sickness or accident must be planned for, since it is not always easy to break in a man on short notice. The same applies to the operation of a chlorination plant. Human reserves are just as essential as mechanical ones.

While not so serious from the health standpoint as dangers resulting from pollution, suddenly occurring odor and taste troubles may set up such a deluge of complaints that the water-works superintendent feels that it is not merely an emergency but a catastrophe which has taken place.

One of the most frequent troubles results from tastes and odors due to the growth of algæ or other plankton. We have had many interesting happenings along this line. Some superintendents have had a great many

of these experiences and by means of regular microscopical analyses and copper-sulphate treatment, they anticipate difficulties pretty well. It is a strange thing that some reservoirs will go along for years without giving algæ troubles and will then suddenly break out with obnoxious growths. About two years ago I had occasion to confer with a superintendent on a small water-supply system in the eastern part of the state and asked him whether they had ever had algæ troubles. He had never heard of such difficulty. About two weeks later, he telephoned that the people were up in arms about the fishy taste of the water. We found a prolific growth of algæ, but the trouble soon responded to copper-sulphate treatment. Now the supply is treated regularly.

In another Connecticut town, we received one day a number of complaints about the chlorine taste of the water. We promptly made residual chlorine tests and taste observations and were at first of the opinion that a temporary overdose of chlorine might have been applied. We made our inspection when the pump was in operation. The same night we received more complaints. We considered the possibility of adverse watershed conditions and cross-connections. Finally we visited the two standpipes, one of which was new; the other was old, but had been painted during the preceding fall. We had a lineman of the power company climb up and sample the two standpipes on an icy winter day and found that the water in the old standpipe had a pronounced tarry taste. When the pump was stopped and the standpipe started to empty, the complaints began. This standpipe was shut off, and the trouble disappeared at once. The paint had been applied to an old uneven surface and had begun to peel off, exposing a soft undercoating which gave a decided taste when placed in water. Whether this sudden trouble was due to increased brittleness of the outside coating at low temperature or some other factor was uncertain.

The Commissioner of Health called me on the telephone one night and said a woman had telephoned him that the water at her house in a town about twenty miles from Hartford tasted like carbolic acid and she was afraid the water supply had been poisoned. We found that hot tar had been applied to the standpipe the day before and that a taste had been imparted to the water. It soon disappeared.

On one large chlorinated surface-water supply about two years ago, in the early winter, a highly disagreeable taste and odor developed and severe criticism resulted. We found that the taste was also present in the untreated water. A contractor for the highway department had just finished a new Macadam road near the reservoir. The tar coating had been applied just as freezing weather came on, so that the material did not penetrate. Then came a thaw and a heavy rain which washed down into the reservoir, causing a decided phenolic taste and odor, which no doubt were accentuated by chlorination.

In emergencies arising from the sudden development of odors and tastes, the water-works superintendent will do well to communicate im-

mediately with the State Department of Health so that their laboratory facilities and field service will be made available and also that the public may be reassured as to absence of dangerous pollution. Treatment of water supplies with ammonia and activated carbon may help out when tastes and odors develop.

Outbreaks of Sickness.

Another emergency sometimes confronting the water-works superintendent is the rumor, which may follow an outbreak of sickness in his community, that the public water supply is infected. The superintendent who has an unfiltered and unchlorinated surface-water supply is sometimes hard up against it in such a case, because samples sent in from his untreated supply may show the presence of bacteria of the *coli-aerogenes* type. This casts suspicion on the water supply even though it is not responsible. Colon organisms are present in the intestinal tract of man and animals. Their presence in water indicates that the natural purification by storage and dilution is not sufficient to take care of dangerous pollution of intestinal origin introduced into the supply. These organisms themselves, however, do not cause sickness. Where a supply is treated by filtration or chlorination, the superintendent should have available a continuous record of residual chlorine and other tests so as to convince the health authorities of the safety of the water supply in the event of outbreaks of disease.

We had one strange coincidence about five years ago in a Connecticut town where a new surface-water supply purified by rapid sand-filters and chlorination was turned into the system just previous to a typhoid outbreak. The system also secured water from an untreated surface supply. The president of the water company asked us if we recommended shutting off the new supply, which rumor held responsible, but we advised shutting off the old supply which did not show up well bacteriologically although the watershed was clean. Very soon afterwards, chlorination was installed on this old supply. The typhoid was later traced to a carrier in a food store, but the epidemic caused the water-works people a lot of worry.

In some sections of the country, extraordinary floods have created serious water-works emergencies although this has not been a serious source of trouble in my own state to date. Every thaw and heavy precipitation causes somewhat of an emergency and requires that the efficacy of filtration and chlorination be checked up because of the increased load placed upon these purification processes at such times.

The water-works superintendent is frequently face to face with some new emergency problem but this is one of the things that make his job interesting and important. Extraordinary emergencies in the order of natural catastrophes can hardly be provided for in advance, but a little private speculation from time to time by the individual superintendent on the emergencies that might reasonably occur is a good deal safer than to sit back and wait for them to descend unexpectedly.

MEETING EMERGENCIES RESULTING FROM BREAKS IN WATER MAINS.

[Superintendents' Discussion, September 30, 1931.]

THEODORE L. BRISTOL.* I have been asked to begin the discussion on the subject, "Provisions for Meeting Emergencies Resulting from Breaks in Water Mains." There are so many important things to do that it is rather difficult to know where to begin. I began with many provisions but finally decided that, first of all, if we get perfect pipe and lay it well we shall not have breaks. Of course inspection at the foundry, inspection when the pipe is taken from the cars, inspection when the pipe is cleaned, and inspection when it is laid and caulked, help a lot. The laying of the pipe has to be very carefully done or there will be breaks caused by imperfect laying.

The second provision is to have all gates in good working order. That can only be done, in my opinion, by operating the gates at least once a year. I think it is well, and almost necessary, to have power operation with big gates.

Third: Cards should be quickly available showing the location of the gates. It is often difficult, when one is not called upon to operate gates frequently, to find out where they are located. If cards are in the office where one can get at them quickly it will help to get the gates shut.

Fourth: Telephone numbers should be listed under the title of the water department for the superintendent and foremen, so that in case of breaks they can be quickly notified. Our men are listed not only under the water department but also under their own names. Since the city is small, most of our men are known to the citizens.

Fifth: There should be a list of industrial plants where city water is used for boiler purposes, so that each plant affected by a break may be quickly notified to control its fires. That is very important where industrial plants are large. We also find that complaints come from pressing establishments in which they may have steam boilers under quite high pressure.

W. A. MACKENZIE.† I can tell about an experience we had on our works some four months ago. We were preparing to make a cross-connection between two main-supply pipes. On a previous cross-connection, at the opposite end of the tunnel, we had four gates, located in a large manhole. The men were shutting off these cross-connection gates about five o'clock in the morning preparatory to cutting the mains for the new connection. They had all of the gates shut with the exception of one on a 10-in. by-pass. That gate was closed, and immediately the top part of the bonnet blew out leaving a hole about four inches in diameter. The two men

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†Consulting Engineer, Wallingford, Conn.

had some difficulty in getting out of the manhole as it instantly filled with water. This installation was put in several years before by a competitive bid on a light-weight gate, because of the low pressure at this location on the pipe line. We had none of this particular type of gate in stock. This left us with only the small main-supply in service. I immediately started our filtration and pumping plant. We could not locate any of the light-weight gates in adjacent towns, so we telephoned the manufacturer and they started a car from the factory and met our car at a half-way city. It took over ten hours to make the repair. This proves conclusively that it is advisable to install a standard heavy-weight gate, even though the pressure does not require it; also to standardize on certain makes and types of gates and hydrants and always to keep parts in stock.

SAMUEL H. MACKENZIE.† Mr. Bristol spoke of having cards of gate locations handy. Our gate locations are recorded on tracing cloth, which we keep in the safe, in the office. Several blueprints or whiteprints have been made from the tracing cloth record, so as to have a gate book for each car and also one in the office, and at the superintendent's house, for use in case of emergency. We have also made blueprints giving the names and telephone numbers of the superintendent and assistants. These are posted in the police station and in the offices and boiler rooms of the different factories. In case of emergency, therefore, some one of our men can be quickly reached.

DAVID A. HEFFERNAN.* Courage and perseverance under unpleasant conditions were demonstrated by our men recently while inserting a valve on a hydrant branch under 130 lb. per sq. in. pressure. Some difficulty was encountered in making a joint tight. Due to the heavy pressure several large jets of water were escaping, but the men stuck to their job in spite of a good wetting until finally the line was shut down and the joint made tight.

Some years ago we were fortunate to obtain the use of a 2½ story building that had been abandoned by the fire department. The upper floors were arranged for living quarters and the street floor for a garage. Arrangements were then made to have a foreman live in the apartment. By doing this the department is ready at all times to take care of emergency calls. This has proved to be beneficial to the town.

To save time in shutting down lines in cases of emergency, the department is making a practice of keeping all gate boxes up to grade and painting covers on boxes yellow for visibility. To prevent prolonged interference of flow of water on main feeders when leaks occur, special repair sleeves may be used.

F. O. A. ALMQUIST.‡ With regard to water-works emergencies, I have in mind two experiences where men were drenched in connection with the testing of double check-valves, the valves being used to protect the public water-supply where cross-connections exist.

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†Superintendent of Water Works, Milton, Mass.
‡Connecticut State Department of Health, Hartford, Conn.

In the first case a man slipped into a manhole and was groping around with one of his feet for a place to rest it when he inadvertently kicked off the gage. While it is only a ¼-in. connection, the flow of water was such that he was well drenched before he could climb out. Fortunately in this case the gate valve was outside the pit. It appears to be a desirable procedure to have at least one gate valve on the city side outside of the pit.

The second case occurred when the gate valve was inside the pit. After pouring the concrete for the pit, the forms were left. The master mechanic, in kicking out the cross braces preparatory to testing the valves, kicked the gage, breaking the connection. The man, on account of a possible fire hazard, stayed in the pit to open the gate valve. He was able to open the valve to within about two turns, before having to come out of the cold water.

Another experience which was unique occurred in one of the water-works systems in Connecticut. The water company thought it was well fortified against an emergency by having two supply mains from the distributing reservoir. During a lightning storm, a bolt of electricity cracked both mains at the same time. The mains were 12 or 15 ft. apart at the point of the accident. Fortunately, they were not cracked so badly that one could not be used while the other was being repaired. The pressure in the system was, of course, lowered until the repairs were completed. In order to eliminate occurrences like this one, it would be desirable to provide storage at the farther end of the distribution system, if only one distributing reservoir is used.

HAROLD W. GRISWOLD.* The question of emergency crews and equipment seems to me quite important. How far a utility is justified in providing emergency crews and equipment was brought home to us last 4th of July, about 11 o'clock in the morning, when a 24-in. line broke. Our practice has been to have two men on duty on holidays up to 5 or 6 o'clock, and three men at night, together with an emergency truck equipped with gate-operating mechanism. We also have telephones in all of the foremen's houses. We have certain other men designated as emergency men, who also have telephones. The emergency truck is equipped with a gate book showing the location of every gate in the territory in which it operates.

In spite of these precautions, we had a great deal of difficulty in getting together an emergency crew. The notification of the break came in before the pressure dropped. We had two calls, and one of the two emergency men on duty went out to investigate at the first call. Immediately he saw it was a serious break and telephoned back to the other emergency man to collect a repair crew. The man at the yard was unsuccessful in getting the first two foremen he called, but he got the third. This foreman picked up one man, came down to the break and was met by the emergency truck, and began to close off the large gates.

It is interesting to see how the family keeps tabs on water-works opera-

*Deputy Chief Engineer, Water Bureau, Hartford, Conn.

tors. A fourth foreman was in a barber shop at the time of the break. His family knew exactly where he was when the telephone message came, and it was only three or four minutes from the time his house was notified before he was on the way to pick up a crew. He collected a crew before he went to the break and began shutting down the smaller gates.

It is a question just how far a utility should go with emergency preparations. Is it justifiable to keep an emergency crew that will take care of all situations that may arise? My answer to that would be: no; it is too expensive. On the other hand, many water works apparently operate with a single man for emergency service. In that case, if there is a small break and he is sent out on it, it leaves the entire system unprotected. It seems to me, therefore, that two men are the smallest emergency crew. If a gate-operating truck is provided there should be three men on call at all times so that the crew will be able to use the truck in operating the large gates.

HENRY T. GIDLEY.* I think that in a great many places not enough gates are put in. I know that is the case in our town, in the older part. We found that out this summer when we wanted to connect a 6-in. pipe to a new 12-in. main that we were laying. We had to shut off about ten gates. Of course it was only for a short time, until we could get the 6-in. gate in. A good many of our hydrants, too, except on the mains from the station, are not gated, and that quite often causes trouble.

While laying the 12-in. main this summer something happened which I had never experienced before. We turned the water on a block of 12-in. pipe, intending to turn it on rather slowly to flush out the main; but the men at each end by mistake turned it on very quickly. About that time I had two calls in the office one after the other. One was from a large residence which had a 2-in. cast-iron service running into the house. The call said they had opened a faucet and could not get a drop of water. I could not understand this at first because the house was so far away from the point where water was being turned into this new main. In fact, I did not know that they were turning the water in. When I got in touch with the crew I found that at the instant when they turned the water into the 12-in. main they had pulled the water away from the two services.

PAUL F. HOWARD.† Winthrop, Mass. probably has a problem which is not common to many other towns. Winthrop is a peninsula forming the outer rim of one side of Boston Harbor. At times it is lashed badly by the sea during storms, causing considerable damage to many cottages along the waterfront. In the vicinity of Winthrop Boulevard and Point Shirley, and especially in sections which have been developed by private capital, bulkheads have been built along the waterfront with a road between the bulkhead and the houses facing the water.

We have found that it is not safe to lay the water mains in these waterfront roads as was done in the past. Hence we now lay them through the back yards of the houses facing the waterfront roads.

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†Of Whitman and Howard, Consulting Engineers, Boston, Mass.

Last winter we had quite a storm which washed out several hundred feet of one of these waterfront roads, taking the water main with it. In order to supply the houses in this area, after the water main was washed out, we connected up a large quantity of small-sized pipe on the surface of the ground and piped it into houses through a kitchen window or any other convenient place. Generally these washouts happen in the winter time; this adds considerably to the problem.

CONSTRUCTION LAYOUTS AND LOCATION OF GATES OF VALUE IN EMERGENCIES.

BY SAMUEL H. MACKENZIE.*

[*Read September 30, 1931.*]

At Southington we have found that duplicate main lines from our reservoirs have been of inestimable value and help in maintaining water service during the flushing of main lines in the town and also at three different times when breaks occurred in one of the lines, especially during the period when our old line was cut out for cleaning. It is necessary to furnish continual service for fire protection, as in most communities the public water supply is the only source of supply.

I often wonder how we got along twenty years ago, when we had but one main. I can remember at that time we had to do repair work and much of our flushing after ten o'clock at night, because, at times during flushing, the supply was practically shut off from the entire community. I fear the insurance companies would in these days object to such operation.

With two main lines from the reservoir, we have been able to flush them alternately and to supply the town with practically no inconvenience to consumers while maintaining sufficient pressure for fire protection.

A short time ago, at our Terryville plant, failure of a gate to close obliged us to cut off half the town from the reservoir supply, but fortunately our Layne well supply was so located in the half shut off, that we could supply it from the well. While the pump was running, we relieved the pressure by opening a 2-in. blow-off.

That experience showed very clearly the advisability of having either duplicate feed lines to as many parts of the system as possible, or a standpipe or pumped supply on the opposite side of the town from reservoirs. If ground-water conditions are suitable, a Layne well or some similar auxiliary supply is one of the cheapest and best emergency supplies that can be provided.

Blow-offs. In the early days of water-works construction, insufficient gates and blow-offs were installed. We had occasion recently to clean our old main line, which was installed forty-seven years ago. At that time the value of numerous blow-offs and of curved pipe at bends was clearly demonstrated, as we were able to send the cleaner through from the reservoir to the river in town, a distance of about eleven thousand feet without making a single cut in the line. We opened the blow-offs ahead of the cleaner, closing them after the cleaner had gone by. Part of the incrustation passed out of the pipe at the blow-offs, thereby reducing the load being carried in the main. This prevented the cleaner from getting stuck.

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I like to have the outlets of blow-offs visible, or in manholes, where they can be inspected.

The expense saved on the cleaning job, by having blow-offs at frequent intervals and curved pipe was quite an item, and the time the main was out of service was materially reduced. For convenience in cleaning a Y was installed in the line below our Venturi meter. All we had to do, therefore, was to shut off the line, take out the plug and insert the cleaner, replace the plug, turn on the water and follow the cleaner through to an opening directly into a river in town. We did a good job. The foreman from the National Water Main Cleaning Co. ran the cleaner through the main twice. It took a little less than two hours from the time the cleaner emerged in the river the first time until it appeared the second time.

Tees for Hydrants. I like the plan, used at Springfield, Mass., of employing bell and flange tees in mains with a flange and bell gate bolted onto the flange of the tee. The advantages of that practice I believe are: the joint between the main and the gate is not liable to be disturbed if a hydrant is hit or broken; there is no danger of the gate being blown off the main; the gate is far enough, as a rule, from the hydrant to be reached if water is running from a broken hydrant; finally, if it is not desired to set hydrants at the time the main is laid, the tees can be capped and a gate easily attached later.

The practice followed in the past, to some extent, of installing flanged hydrants directly on a bell and flange gate, in my opinion, is not good. The joint back of the gate is more likely to be loosened than the flange joint if the hydrant is pushed over, thereby making it necessary to shut off the main to make repairs. The gate, furthermore, is so close to the hydrant that it may be impossible to get a wrench onto it if the hydrant is broken and water is running.

Plugs. Practically all of the plugs in the older part of our system were solid, but of later years we have used tapped plugs and have found them of great convenience in several instances.

Gates. All hydrants should have gates, and gates in mains should be located at street intersections and at frequent intervals in mains laid in streets where intersecting streets are some distance apart. If there are parallel mains, a cross-connection should be installed for each section if possible. In case of trouble, but one section will then have to be out of service. Distances to hydrant gates can be marked on brass tags attached to hydrant chains. This marking is not always permanent; boys have been known to steal the tags.

Service Pipes. Forty to fifty years ago ¾-in. galvanized pipe seems to have been the customary size for services. In many of the smaller plants not much attention seems to have been given to how or where service pipes were laid, and in many instances no locations were recorded. If it was not for the pipe locator now in use, much difficulty would have been experienced in locating the pipes and the taps at mains. We now require that

service pipe, where it is possible to do so, be laid straight from the main to the cellar with a plug in a tee in the cellar. Where pipes have been laid in this way, it is easy to inspect, clean and thaw-out the services when necessary at a small expense, thus saving property owners many dollars.

We have been quite successful in cleaning 1 and $1\frac{1}{4}$-in. galvanized services. At times after we had pushed the cleaner as far as possible in the service without getting a good flow of water, we have found a stoppage in the corporation stops. These we used to dig up and clean, but at the present time we have been successful in removing the obstruction by pumping in gumdrops. One reason for stoppage by corrosion is that corporation stops are not screwed far enough into the main and products of corrosion build up at the end of the cock. We realized twenty to twenty-five years ago that $\frac{3}{4}$-in. galvanized pipe was not adapted for services and began installing 1- and $1\frac{1}{4}$-in. galvanized pipe. We have now learned that the use of additional fixtures on most services and the greater draft of water results in the life of the 1-in. pipe being shorter than that of $\frac{3}{4}$-in. pipe in the old days. We are now using cement-lined wrought-iron pipe, red-brass pipe, or copper tubing, and we trust that some of the difficulties have been overcome.

TUBERCULATION OF MAINS AS AFFECTED BY BACTERIA.

BY H. G. REDDICK* AND S. E. LINDERMAN.*

[*Read September 30, 1931.*]

One of the most baffling problems which confronts water-works men today is the growth which forms on the inside of pipe lines in various localities. This growth is referred to as "tuberculation" and was doubtlessly observed on some of the oldest installations of cast-iron pipe within a comparatively few years after installation. Previous to the middle of the Nineteenth Century little consideration had been given to this phenomenon. The effect of tuberculation upon the early pipe lines must have been serious, however, as the first lines of cast-iron pipe which were installed did not possess the tar coatings or cement linings which modern water-works engineering demands.

FIG. 1.

A tubercle has been described as follows†: A limpet-like structure arising from the surface of iron. In time the surface becomes studded with these objects much the same as a ship's bottom becomes covered with barnacles. Each one of these incrustations consists of a cone-like structure which grows by the addition of concentric layers. The central portion is black and soft when fresh. This black substance often contains a small percentage of sulphide of iron and becomes red upon exposure to air. The middle layers are composed of ferric oxide. The outside layers are composed for the most part of ferric oxide interspersed with hard black layers of magnetic oxide of iron.

"In a report issued by the New Bedford, Mass., Water Board in 1913, we find there was considerable tuberculation of both steel and cast-iron

*U. S. Pipe and Foundry Co., Burlington, N. J.

†Ellis: Iron Bacteria.

pipe. Regarding the tuberculation of cast-iron pipe at New Bedford, the report states the following:

"In the cast-iron pipe, the tubercles themselves have grown considerably in size. The extent of this growth is best indicated by the four outer rings, which can be clearly seen on photographs, showing the under or contact side of tubercle. Photographs showing the top and side view of sample tubercles from the cast-iron pipe are also submitted.

"Samples of tubercles from the cast-iron pipe which enters the High Hill Reservoir gatehouse were collected, and analyses of the soft central or middle portion thereof and of the tubercles as a whole were made. Results of these analyses are as follows:

ANALYSES OF TUBERCLES.

"Sample marked No. 3, soft central portion of tubercles from 48-in. cast-iron pipe which enters High Hill Reservoir gatehouse.

	Per Cent.
Silica and insoluble matter	3.23
Ferric oxide, Fe_2O_3	69.12
Alumina and Lime, Al_2O_3 and CaO	traces
Sulphuric anhydride, SO_3	1.36
Water of hydration, H_2O	26.28
Carbon dioxide, CO_2	none

"Sample marked No. 4, whole tubercle from 48-in. cast-iron pipe line as above.

	Per Cent.
Silica and insoluble matter	1.78
Ferric oxide, Fe_2O_3	68.62
Alumina and Lime, Al_2O_3 and CaO	traces
Sulphuric anhydride, SO_3	.55
Water of hydration, H_2O	28.16
Carbon dioxide, CO_2	none

Although the authors have not examined the specimens of tuberculation from New Bedford, samples were obtained from old cast-iron pipe, which had been in service in Falmouth, Mass., Burlington, N. J., Philadelphia, Pa., Louisville, Ky., Petersburg, Va., and Chicago, Ill. Examination of these specimens revealed that all of them possessed very similar characteristics. Their percentage chemical composition was found to be as follows:

	Falmouth, Mass.	Burlington, N. J.	Philadelphia, Pa.	Louisville, Ky.	Petersburg, Va.	Chicago, Ill.
Iron	54.54	57.68	55.33	58.93	56.03	48.21
Silica	1.42	3.95	4.20	1.08	2.07	10.54
Phosphorus	.24	.23	.15	.13	.08	.11

In connection with the experimental work which has been carried on by Dr. David Ellis, the authors have compared these findings with analyses of bog ores and limonites. These analyses reveal a close analogy:

	Bog Ores from		
	Pennsylvania.	Massachusetts.	Oregon.
Iron	56.30	47.52	44.71
Silica	5.16	—	—
Phosphorus	.13	.19	.66

Furthermore, all of these tubercles are magnetic as is bog ore. All of these tubercles contain water of hydration, as does bog ore. All of these tubercles seem to be nodular excrescences grown by accretion and formed of concentric layers as is limonite. Limonite or brown hematite ores are nodular in character like the inside of a tuberculated pipe where the tubercles are closely packed. It is the pleasure of the authors to present substantiating data that these nodular excrescences, or tubercles, found on the inside of cast-iron pipe are of bacterial origin.

With such evident similarity between the tubercles and the bog ores, it was only natural to assume that possibly these two products are formed in much the same manner. Several bacteria have been isolated from time to time which show a decided ability to precipitate iron oxide out of solutions of iron salts. As to how this is accomplished is a debatable question. Some investigators believe the reaction is physiological, others that it is purely mechanical. However, be that as it may.

It is well recognized and known that bacteria of certain defined types, known as higher bacteria, are potent if not sole factors in the formation of bog ores, brown hematites, as well as ocher beds and brown ironstone clays. Winogradski, Molisch, Ehrenberg, Adler and Ellis have contributed much information relative to these so-called iron bacteria.

These bacteria belong to a class known as higher bacteria. They are much larger and present forms resembling plants on a higher evolutionary plane. They possess the ability to collect iron, sometimes in their bodies, sometimes on the outside of their bodies. The weight due to this added iron carries them to the bottom of a lake and thus is formed an ocher bed. In the case of bog ores and limonites they attach themselves to some rough surface, colonize, multiply and grow on the outside of their own dead bodies and colonies, thus building up a formation nodular in character and of concentric layers.

K. Braddock Rogers, of the University of Pennsylvania, in an article on "The Bog-Ore Industry in South Jersey Prior to 1845" writes regarding *Crenothrix*, "this filamentous bacterium oxidizes and precipitates the iron about any firm object upon which it can cling. Deposits which have been made in this manner have taken the exact form of tree stumps, trunks, branches and root systems."

Ellis records that Molisch found ocher-colored masses in the waters of Austria and Hungary and that these masses consisted of the dead threads of *Leptothrix*. He also found this condition in both the Tyrol and Bohemia. In Belgium, in deposits of 208 iron-bearing waters, Schwers found this same organism in 142 samples. Ellis shows that this and other iron bacteria have been found in Great Britain, Scotland, Russia, Spain and Denmark, and Molisch found them in Ceylon, Java, China, Japan, U. S. A., and Canada. *Leptothrix*,* *Gallionella** and *Spirophyllum** are the bacteria which are well-known agents in the formation of ocher beds and bog ore. Another bacterium, *Crenothrix** *polyspora* (Cohn), which is known to be such an iron gatherer that it has been termed the "well pest" achieves what has been termed a "calamity growth." Ellis says it has multiplied so rapidly "that its results are visible to the naked eye in the form of a transformation of the normal color of the water into a reddish brown color." It is evident, therefore, that these so-called higher bacteria gather iron and are potent factors in the formation of bog ore and limonite.

In view of the fact that the physical and chemical properties of the tubercle are so similar to limonite and bog ore, and that both are hydrated magnetic oxides of iron, and that it is known that bog ore is formed largely by bacteria, the thesis that tubercles are caused by bacteria seems tenable.

The three forms of iron bacteria whose skeletal remains have been found in bog-ore deposits from wherever it has been examined are *Leptothrix ochracea* (Kuetzing), *Gallionella ferruginea* (Ehrenberg) and *Spirophyllum ferrugineum* (Ellis). An effort was made to find one or more of these bacteria in the specimens under investigation. Skeletal remains of *Spirophyllum* were found in the Philadelphia pipe. In the Burlington pipe *Spirophyllum* was found in the sludge. *Gallionella* and *Spirophyllum* were found in the sludge sent us from Falmouth.

In our attempts to cultivate these bacteria the following culture media were chosen:

I. *Iron Gelatin.*

Gelatin	120 grams
Peptone	5 grams
Beef Extract	3 grams
Ferrous Sulphate	1 gram
Water to make	1 000 ml.

II. *Iron Agar.*

Agar Agar	15 grams
Peptone	5 grams
Beef Extract	3 grams
Salt	8 grams
Ferrous Sulphate	1 gram
Water to make	1 000 ml.

*Editor's Note: Present nomenclature distinguishes between *Leptothrix*, *Didymohelix* (formerly *Gallionella*, *Chlamydothrix*, or *Spirophyllum*), *Crenothrix*, *Sphærotilus* (formerly *Cladothrix*) and *Clonothrix*.

Forms other than the well-known iron bacteria were also encountered. This we hope will lead to investigations by competent bacteriologists, and will be of importance to the water-works engineer, from two standpoints, namely — obstruction of water pipes and contamination of the water supply with especial emphasis upon the word contamination.

Cultures were made (1) from a 12-in. piece of 4-in. pipe submitted by Burt Hodgman from Falmouth, Mass., (2) from a pipe taken from Wood Street, Burlington, N. J., and (3) from a pipe taken from Philadelphia laid in 1819 and in service for over a hundred years.

The method of making cultures was as follows: (1) Falmouth, Mass., — fresh tubercles and water were submitted in a sealed mason jar. From this, 1 cc. of the sludge was put in a Petri dish together with iron agar. Colonies were allowed to grow; (2) Burlington pipe,— fresh tubercles and water were taken from the pipe in the ground, delivered to the laboratory and treated similarly to the preceding sample.

In passing, a few words regarding the specimen of pipe removed from Philadelphia are not out of order. This nine-foot length of cast-iron pipe was laid under Broad Street, Philadelphia, in the year 1819. During excavations for the South Broad Street subway in 1926, it was necessary to remove certain portions of this pipe line which had been in service continually since the date of installation. This cast-iron pipe having served Philadelphia for over 100 years and being still in excellent condition naturally had considerable historic as well as advertising value. The United States Pipe and Foundry Company was fortunate enough to be able to obtain this length of pipe from the Philadelphia Water Department, and this section has been on exhibition in our General Offices since 1926. While the interior of the pipe was affected somewhat by tuberculation, the condition was not serious. However, the samples previously mentioned were obtained from the pipe after it had been exposed to the air and to room temperatures for approximately four years. These samples were ground in an agate mortar, put in sterile distilled water and shaken; 1 cc. was then introduced into a Petri dish with the iron-bearing agar, and colonies were allowed to grow. Incubation was at low room temperature (60°–70°F.) and in the dark or in subdued light.

After colonies had developed to considerable size, it was noticed that there were three different kinds of colonies which were of reddish brown color: (1) a large round colony, having regular edges (2) a small round colony having regular edges, and (3) a large colony with irregular edges. These are shown in Figure 2, which is a photograph of a Petri dish containing iron-bearing agar on which the colonies are growing. Figure 3 is a photograph showing an iron-agar slant inoculated from one of the large round colonies. The growth of this organism possesses a reddish brown color. Figure 4 is a photograph of a stab culture from the same colony in iron-agar. Ferrous sulphate to the extent of 0.01 gram was introduced in this tube and the top red portion of the agar was removed and the iron

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

determined. This top portion contained .009 gram of ferrous sulphate. In other words, 90 per cent. of the ferrous sulphate had been collected by the bacteria in 72 hours. Figure 5 shows a stab of iron-agar from the large

FIG. 6.

FIG. 7.

colony with irregular edges and Figure 6 shows one from the small round colony. It was found that the large colonies gather iron more rapidly than the small colonies. Figure 7 is a photo-micrograph of the bacteria which

form large round colonies and Figure 8 is a photo-micrograph of bacteria forming the large colonies with irregular edges. The bacteria producing the small round colonies were small bacteria as may be seen in Figure 9.

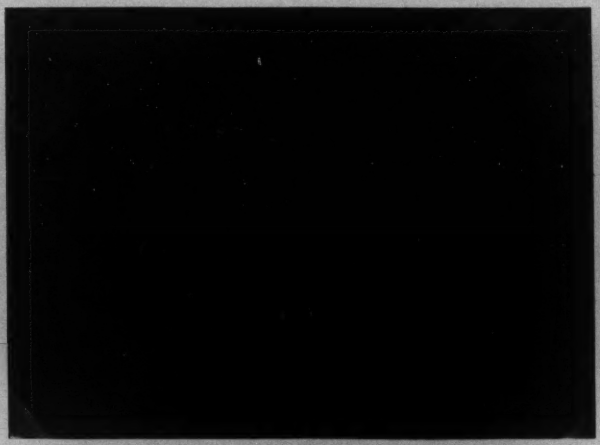

FIG. 8.

FIG. 9.

Another fact regarding these bacteria, which as yet have not been identified, is that they do not need iron to live. Figures 10 and 11 show cultures from the brown colony from which the culture represented in

Figure 3 was made. The slants shown in Figures 10 and 11 contained iron-free agar and the growth is white, while the growth in the iron-bearing agar is reddish brown. Bacteria from all of the three colonies mentioned produced the same result. These, it should be remembered, are not higher

FIG. 10.

FIG. 11.

FIG. 12.

bacteria but ordinary bacteria, which may or may not be ordinary germs such as those found in air and water.

It has been contended that such small percentages of iron as exist in many waters would not allow such a collection of iron. In an abstract from *Western Construction News*, Carl Wilson says, "A well water at Wilmington, California, treated with iron chloride gave a residual iron content of 0.025 p.p.m. This water was found subject to *Crenothrix*

growths, notwithstanding the statements in the literature to the effect that at least 0.2 p.p.m. is required to promote such growths." This supports our contention that iron is not necessary to the growth of either the higher bacteria or of the ordinary bacteria which are iron gatherers, notwithstanding the statements of Lipman and Koch, that *Azotobacter* will not

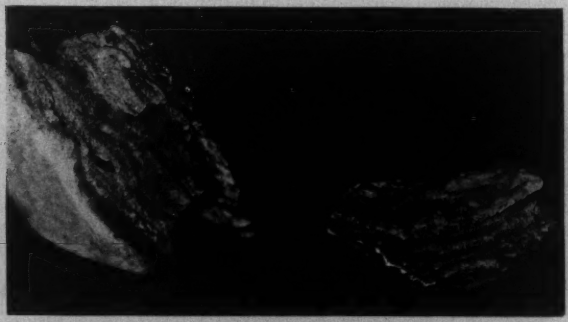

FIG. 13.

FIG. 14.

develop in culture media devoid of iron. This, however, might refer to iron in traces so minute as to be negligible as compared to that with which we are concerned in this article. When we say they do not need iron to grow, we mean that none of the materials used in making the media contained iron, except the minute traces which might be found in the agar, gelatin, or other ingredients, and that the growths showed no iron colorations whatsoever.

In the case of the pipe from Falmouth, Mass., Figure 12 shows a pipe which was entirely closed. The amount of iron ore which came out of this pipe is remarkable, yet the pipe, itself, is scarcely attacked, the coating even being intact in a large part of the internal area. Figure 13 shows tubercles taken from this pipe. This iron was gathered for the most part from the water by microörganisms.

The germs which we have found to be iron gatherers will live at quite a wide range of temperature. All inoculated cultures grew at 65° C. Figure 14 shows a growth on an agar slant which was frozen at 0 to 10° F. for three weeks. Some of the ice water gathered upon thawing out the tube,

FIG. 15.

was poured into a Petri dish and heavy growth resulted, the ice water was laden with germs. Also, a plate was inoculated from the reddish brown streak, and growth resulted, showing conclusively that the organisms live at all ordinary temperatures in this climate. Another feature, from a bacteriological standpoint, is that the germs which we have found to be iron gatherers are what bacteriologists call Gram-negative.

Outside of the sanitary problem, the important feature to the water-works engineer is that there are bacteria other than the well-known iron bacteria which gather unto themselves iron oxide from iron-bearing waters. Because of their rapid multiplication these bacteria become a menace to pipes. Since waters laden with iron will stop up a pipe more quickly than waters with a low iron content, any iron added for coagulating purposes may become detrimental to the water service or even to the community.

The iron mongers previously described have also been found in an open spring near Burlington, N. J., in which all the rocks were covered with a deposit of iron oxide. We made an agar stab of this water and succeeded in growing *Leptothrix*, *Gallionella* and *Spirophyllum*, photographs of which are shown in Figures 15 and 16. Figure 15 shows *Spirophyllum* and *Leptothrix*. *Leptothrix* is shown to form long filaments. *Spirophyllum* resembles a twisted ribbon. Figure 16 shows *Gallionella* resembling a

FIG. 16.

twisted hairpin, the open portions of the twist becoming filled with the collection of iron oxide. The ordinary bacteria of which we have been speaking, which we have watched collect iron, are all aërobic and liquifying. Other characteristics such as flagellæ, spores and identification reactions are omitted as of no interest except to bacteriologists.

Chemical Abstracts for August 20, 1931, states that Kazue Tsukunaga reports having found the previously mentioned iron bacteria in a water pipe in Manchuria, along with *Crenothrix polyspora* and *Siderocapsa major*, the latter being a new iron bacterium discovered by Karl Redinger and reported in *Archiv für Hydrobiology**. This bacterium is said to be surrounded with a gelatinous capsule which contains iron and manganese.

In conclusion, it is our belief that both the higher bacteria and the lower ones were instrumental in the formation of the bog-ore deposits in South Jersey and that they are identical with those we have shown to

*Vol. 22, 410 (1931).

exist in the specimens examined. We feel, therefore, that a problem of importance is herewith presented to water bacteriologists. How best to treat the water supplies of this country, in localities where tuberculation is prevalent, as a means of destroying these various microörganisms or of preventing their colonization is an important problem.

In line with the evidence given it is not necessary that there be any great corrosion of the pipe in order that tuberculation may set in, since the iron-gathering bacteria may get their iron from the water which is flowing through the pipe. The important point is that they must have a minute spot of bare iron where the iron concentration is high so that they can secure a footing. With some organic matter to furnish food they will multiply rapidly. They collect iron from the surrounding medium, be it water or any other fluid or material. When once they secure a footing, they colonize and build up a tubercle the rapidity of growth depending upon the amount of suitable food and whether there is sufficient iron in the medium with a suitable pH value, preferably slightly acid. Inasmuch as all tar coatings have minute pinpoint holes and consequently spots of bare iron (as may be determined by the ferroxyl test), pipe lined with tar offers an opportunity for the colonization of iron-gathering bacteria. This is the reason why pipes need some lining other than tar if tuberculation is to be prevented in tuberculating-water districts. Several types of linings are available which are quite satisfactory in the prevention of tuberculation. Among those in common use are cement and bitumastic enamel. Linings should be applied centrifugally to give an even and homogeneous protective cover to the surface of the iron, in order to present a surface so perfect that any iron-bearing bacteria present in the water supply cannot readily find the lodging place whereby contact is made with the bare iron. This contact is favorable to the formation of a tubercle.

An important factor in retarding the growth of iron bacteria is that the surface of cement linings is alkaline. Our investigations to date have lead us to believe that an alkaline iron-bearing water, having only a small content of organic matter, will not tuberculate, and that a slightly acid water containing iron and having a high organic-matter content will readily tuberculate. The iron bacteria which are present in the water supply will remain dormant under the former set of conditions. It follows that the cement lining of pipes is important, because it produces a medium completely covering the inside of the pipe and, at the same time, creating a chemical condition antagonistic to the formation of tubercles.

As an added point of interest there is presented, Figure 17, a map of the United States upon which are indicated areas where tuberculation is known to exist in varying degrees. This map was prepared on the basis of information obtained from a questionnaire sent to water-works companies throughout the United States by the Sectional Committee of the American Standards Association on Specifications for Cast-iron Pipe.

As an example of the information shown in Figure 17, we find that

at Charleston, S. C., the water supply is derived from a surface source and produces severe tuberculation. The water has a low pH value and a high organic-matter content. Severe tuberculation took place at Charleston necessitating the cleaning of the distribution mains several times. Milk of lime was first used to maintain a high alkalinity. This brought objections from householders. Caustic soda was then used and it was found by doing

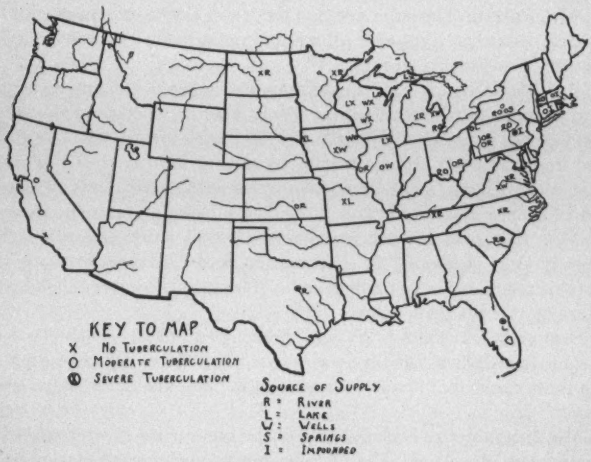

FIG. 17.

so that the CO_2 content could be brought to zero if desired and the pH value maintained at any desired figure. This addition of soda, furthermore, softened the water.

It is interesting to note that Mr. J. E. Gibson, Manager and Engineer of the Charleston Water Department, concluded an article regarding the tuberculation at Charleston mains as follows: "The Department feels that with the combination of the new method of treatment of the water and the cement lining of cast iron mains it has materially overcome its difficulties."

DISCUSSION.

MALCOLM PIRNIE.* Have these studies been carried far enough on the alkaline side to determine whether or not manganese coatings are formed after the pH reaches a point at which iron coatings no longer form? Therefore, does manganese deposit on cement linings or cement aqueducts when iron bacteria do not appear on these surfaces?

*Consulting Engineer, New York, N. Y.

H. G. REDDICK. One thing may be said about this question. All the tubercles examined contain manganese, some much more than others. A few months ago a Japanese investigator found tubercles in a water pipe in Manchuria in which the manganese was quite high. In other districts, too, tubercles contain considerable manganese.

MR. PIRNIE. This occurs in alkaline waters?

MR. REDDICK. Yes.

MR. PIRNIE. The more alkaline the water the more manganese?

MR. REDDICK. Probably so, within limits, but we have not made the necessary experiments to prove it.

ELWOOD L. BEAN.* Mr. Linderman has spoken of alkalinity, in general, being a controlling factor. Is it the total alkalinity or is it the pH which he considers the controlling factor? For instance, with a water containing some iron and little organic matter, is raising the pH to 9.0 or slightly higher a controlling factor, or would a water with an alkalinity of 30 rather than 10 have a greater effect in producing tuberculation at the same pH?

MR. REDDICK. In ordinary bacteriological work the pH value is generally kept at about 7.0. Between 6.0 and 7.0 seems to be the most favorable region for bacteria in general. There are, however, some bacteria that grow at a pH value above 7.0.

STEPHEN H. TAYLOR.† We find in New Bedford that with pipes, from the same foundry and, as far as we know, treated exactly alike, there will be in some cases, quite bad tuberculation in one pipe and perhaps none in the next.

MR. LINDERMAN. Probably one of the pipes has a greater rate of flow of water than the other. The bacteria must have organic matter to live. They do not live on the iron. They simply gather that in their process of growth. With the pipe and everything else the same, except the organic matter, tuberculation can occur in one pipe and not in another.

H. J. COOK.‡ I have noticed that there are more tubercles on the bottom of the pipe than on the top.

MR. BEAN. At Providence pipes laid over fifty years have both corrosion and tuberculation in sections from 1 to 2 feet from the ends of the pipes only; the rest of the pipe is perfectly clean.

JOHN T. ROBERTSON.§ I would like to ask Mr. Linderman if he thinks that either cement or bitumastic linings would tend to inhibit bacterial growth.

MR. LINDERMAN. We feel that both would.

MR. ROBERTSON. Some time ago we cleaned a supply main which had been in service for sixteen years. There were some tuberculation and quite a bacterial growth on the interior of the pipe. The value of the discharge coefficient C had fallen to 91 or 93 in sixteen years. By cleaning the pipe

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†Superintendent of Water Works, New Bedford, Mass.
‡Superintendent of Water District, Auburn, Me.
§Chief Engineer, Consolidated Water Co., Utica, N. Y.

we raised it to 131. We find, now, that in order to maintain an average C of 120 we have to clean the pipe about every eighteen months. The pipe tuberculates more rapidly now than it did formerly.

MR. LINDERMAN. No test has been made of pipe with bitumastic lining. A theoretical value of C of about 150 may be obtained. Mr. Esty can probably tell us whether slime has formed at Danvers on cement lining.

ROGER W. ESTY.* In 1926 we laid a 20-in. pipe from the reservoir to the center of the town. Last week we had to change some 800 ft. of it due to a change in grade of a railroad track. In salvaging this pipe we noted that it had just a little slimy coating on it. Just as soon as the coating dried it could be rubbed off by hand. The smooth, glossy surface of the cement lining had disappeared; the surface was similar to that of fine sand paper. Apparently there had been no action on the lining to a depth of more than 1/64 inch.

I would like to ask Mr. Linderman if there is any advantage in spraying cement linings with pipe dip.

MR. LINDERMAN. We do feel that there is an advantage. We have prepared some paint which we feel has a very definite place. Mr. Reddick can tell us something about that.

MR. REDDICK. We have made a paint which can be applied to cement linings. This paint definitely stops the leaching action of the cement. The paint has a pitch base. No taste or odor from this paint is imparted to the water.

MR. ESTY. Has the paint been used and later removed from surfaces to see whether or not there has been any action on the cement behind the paint.

MR. REDDICK. Our leaching test was run for five weeks. No leaching was observed in that time.

MR. PIRNIE. Referring back to Mr. Robertson's statement about the 12-mile pipe line of 24-in. pipe at Utica, it is interesting to note that this line is cleaned every 18 months at a cost considerably under $1 000. Recently, I made a study to determine what was going on in the pipe. My feeling was that the pipe was acting as an iron removal plant and that Mr. Robertson might charge the cleaning to purification instead of to maintenance.

Normal operation at Hinckley Reservoir was to use the bottom intake entirely. After the winter stagnation period, and again during the summer stagnation period, the iron content of the water in the lower intake was considerably higher than in water drawn from the upper intake. We determined the iron content of the water in the upper end of the 12-mile line and at the lower end where it discharged into Marcy Reservoir. Early in June there was a very large reduction of iron in the water as it passed through the 12 miles of 24-in. pipe. The rate of reduction amounted to between 7 and 9 tons of iron a year. I do not believe that it is as great as that throughout the year.

*Superintendent of Water Works, Danvers, Mass.

Following these determinations Mr. Robertson shifted draft to the upper intake. Subsequent tests showed little change in the iron content between the upper and lower ends of the pipe line. A later investigation showed that iron was still depositing in the main at the rate of one ton per year.

With these data in mind one can realize the benefit which accrues by careful selection of the point of draft from the reservoir at all times of the year. Operation is driven up from the bottom by the iron and down from the top by the algæ. Forced to choose between "the devil and the deep blue sea" it is best to select a happy medium. Unless the iron and manganese in the bottom water can be eliminated, the algæ tastes and odors near the top must be combatted. Somewhere in between it is possible, as Mr. Bean can report from his experiences at Providence, to reduce by nearly 50 per cent. the amount of iron and manganese which will be discharged into the distribution system to cause incrustation in the pipes or to deposit the manganese when the pH is adjusted to prevent corrosion.

MR. COOK. I would like to ask how long tastes associated with the use of cement-lined pipes last. I have noticed a taste in water that has passed through cement-lined services.

MR. PIRNIE. In connection with a large mileage of cement-lined pipe in West Palm Beach, Fla., we attempted to get along without correcting the corrosive properties of the water produced by the mechanical filter plant which includes aëration of the filter effluent. The water went into the mains with a pH of about 7.0. At the ends of the distribution mains the pH built up to about 9.0, and the alkalinity increased comparably with the increase in pH. Later, in order to cut down general red water troubles and possible destruction of the cement lining, we resorted to lime treatment of the filter-plant effluent, increasing the pH to about 9.6. Under the circumstances nearly all of the alkalinity was changed into carbonate alkalinity. After this corrective treatment went into effect, there was no marked increase in the alkalinity of the water as it passed through the cement-lined pipes. I can't tell just how much of the stability of alkalinity was due to final leaching out of alkalinity from the outside coating of the cement lining and how much was due to corrective treatment of the water so that it would no longer attack the cement lining.

I would like to make one other suggestion in regard to cement-lined mains. Distribution systems often consist almost entirely of unlined cast-iron pipe. Under these conditions it is advisable, when making extensions which are going to be dead ended for a protracted length of time, to use cement-lined pipe and thus to avoid excessive incrustation of iron pipes brought about, probably, by the bacterial action which has been described by Messrs. Reddick and Linderman. The capacity in dead ends, which ultimately will be extended as a part of a future distribution system, will thereby be maintained. With some of the soft, iron-containing waters of New England and the South, it is to be expected that unlined cast-iron

pipes, before they become a part of the grid-iron system, will possess discharge coefficients that have been reduced to 90 or even 60.

MR. COOK. What effect does chlorination have on the iron bacteria?

MR. REDDICK. It will destroy them.

MR. COOK. Are plants in which the water is chlorinated having less tuberculation than they did before chlorination?

MR. REDDICK. I imagine that they do not have so much tuberculation after the chlorination, other things being equal.

SIDNEY S. ANTHONY.* I would like to inquire if the composition of tubercles is the same in cast-iron pipes as it is in galvanized wrought-iron pipes which fill up so that you can't see through them in fifteen years.

MR. LINDERMAN. Yes, I believe it to be exactly the same.

MR. ANTHONY. Why does rust accumulate so much faster in wrought-iron pipe than in cast-iron pipe?

MR. LINDERMAN. Because the pipe is smaller.

MR. ANTHONY. We have a 24-in. cast-iron main which has been in service for twenty-five years, and it does not average one tubercle to a square foot; but $\frac{3}{4}$-in. service pipe which has carried water for twenty-five years is filled up so that you can't see through it.

SAMUEL H. MACKENZIE.† Our experience has been that the services through which most water passes corrode the fastest, implying that dead water has a tendency to produce less corrosion. In one instance a service was practically stopped, while another pipe in the same house was practically free from corrosion. The one that was badly corroded was leaking water continuously on the toilet line, while the one that was not affected did not carry much water.

DAVID A. HEFFERNAN.‡ I have had experience with surface and ground waters. When I first came to the Milton plant, water was purchased by the Hyde Park Water Company, the water being obtained from wells along the Neponset River. The analysis of this water showed it to be high in hardness and with an excess of carbon dioxide. In 1902, we entered the Metropolitan System, and it is hard to say which of the two systems is responsible for the present condition of our mains. During the last five years, under the recommendation of our consulting engineers and also as a result of flow tests made by the New England Insurance Exchange, we have been spending a considerable amount of money in enlarging our mains for better fire protection. The size of the pipes removed was 4-, 6- and 8-in., most of them having been in service for forty years. Examination of these pipes showed the 4-in. lines to be almost completely filled with tubercles, in my opinion, reducing the capacity of the pipe almost 60 per cent. The 6- and 8-in. pipes were dirty, but under ordinary conditions would give satisfactory domestic service. Most of the pipe removed was junked, as it

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†Superintendent of Water Works, Southington, Conn.
‡Superintendent of Water Works, Milton, Mass.

was believed inadvisable to reclaim it at the present market price for new pipe.

All our main installations now are of cement-lined pipe. I would like to bring to the attention of the water superintendents in the smaller communities the importance of realizing that the day has passed for installing 4- and 6-in. mains, particularly where modern fire apparatus is used. If smaller pipes must be employed, I suggest that cement-lined pipe be considered. Milton has been using cement-lined main pipe for six years, and we have had satisfactory results from it. You have heard of unfavorable results where cement-lined pipe is used. Some of the complaints are: (1) Scoring of the lining; (2) cement taken into solution; (3) scum on the water affecting kitchen utensils. These conditions can be avoided.

We lay several hundred feet of pipe, then use a testing plug equipped with a 2-in. valve and a 2½-in. hose connection. This gives a chance to test the pipe and also provides water for backfilling. The test water assists in flushing the newly-laid main. On dead-ends the pipes have to be flushed often. Good practice in this case is to tap the pipe near the end for use as a bleeder, if no hydrant is installed. From my own observation a protective film on the lining of the pipe is soon formed.

CHARLES W. SHERMAN.* I recently had an opportunity to see a section of the old-style cement-lined pipe which had been in service since, I think, 1877. It was taken out this year. This pipe was nominally 17 in. in diameter, but actually measured a little over 16½ in. It was made of wrought-iron sheets, probably about 1/16-in. thick, riveted, coated with tar, and cement-lined. The lining was of the style usually employed at that time, a Rosendale cement mortar, made probably with one part of cement and two parts of sand. It was applied by means of a cast-iron cone drawn through the pipe, set in vertical position, the cone being guided so as to center properly in the pipe, and leaving the lining probably ½-in. thick. After curing, the pipe was put into the trench and the joints made with some type of sleeve. The outside of the pipe was coated with a similar mortar mixture, shoveled into the trench and spread over and around the pipe. The section that I saw, which had been taken out, had no vestige of exterior coating remaining,—that is, no cement; the tar was still in good condition. Naturally there was no great strength to that mortar mixture, and when the pipe was taken out of the trench the outside cement coating crumbled away. The interior lining was in remarkably good condition. It did not look quite so good as modern cement-lined cast-iron pipe which we have been told had a surface, after being used a year or two, as smooth as fine sandpaper. I should say it resembled a medium or coarse sandpaper, doubtless due to a larger proportion of sand in the mortar. The mortar was not hard; it could be readily scratched with a steel tool, and probably by five minutes' scratching one could readily go through the ½-in. layer of mortar without bearing on very hard. Nevertheless, the arch action held the cement

*Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

lining in place. There was no evidence of tuberculation and no indication that there was any more damage to the sheet iron pipe on the inside than on the outside of this particular pipe. I ought to say that it had been in a locality where the pressures are low, the maximum pressure being 65 lb. per sq. in.

In view of all the knocks those old cement-lined pipes get, it is interesting to see some that have stood up well; as far as condition is concerned, they might continue to serve for a long time to come. I do not mean to imply, however, that if I were considering buying works in which that kind of pipe was used, I would not figure depreciation as against the cost of building the works new.

CHARLES W. MOWRY.* A good deal of that pipe was used in the city of Lynn. After a very severe lightning storm there were numerous punctures in the pipe, and it was assumed that the steel shell, being insulated on both sides, acted as a huge condenser, and as the potential built up just before the stroke, the lightning punctured the plate and there were many breaks in the line.

JAMES W. GRAHAM.† There is one phase of cement lining that has not been mentioned both in connection with cement-lined mains and the cement-lined services. That is the crumbling off of very small particles of cement which get into meters and wear out their gear trains. Up to within two years ago Portland had very good experience with meters. We scarcely ever had trouble with the gear train. But for the last two years they have been wearing out rapidly. A short while ago in one of our outlying districts we had occasion to investigate the stoppage of a hot-water system, the particular house being supplied through about a mile of 12-in. cement-lined main. We found that the brass pipes were completely filled with a black substance which we were led to believe was made up of small particles of cement. On examining the meter we found that it had a coating on it and that the gear train was completely worn out after about two years of service.

MR. HEFFERNAN. I should like to speak regarding stoppage of meters through the use of cement-lined pipe. In Milton we are 100-per cent. metered and have been for forty years more or less. The majority of our services are cement lined. As my length of service in the Water Department covers this long period I can honestly say that no trouble has ever come to my attention whereby the meter was affected by the cement used in the lining of the pipe. We have been using cement-lined mains for six years with very good results. Special attention is given to the cutting of the pipe, pipe cutters being used instead of chisels. The pipe is also tested and given a thorough flushing after being laid.

Good results have been obtained in Milton from the use of cement-lined services in spite of the following annoying conditions sometimes

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†General Manager, Portland Water District, Portland, Me.

found: (1) galvanic action when brass is joined to iron; (2) stoppage in corporation cocks due to shank not extending inside the main; (3) faulty joint (especially when wiped); (4) lead pipe not heavy enough; (5) expansion and contraction at the gooseneck; (6) use of rigid joints.

By our method of installation all these bad features are eliminated, and we are assured of a continuous line of pipe free from danger of corrosion or obstruction between the main and the meter because our curb cocks and fittings are lined with lead. I would like to call attention to the misleading specification of lead pipe, the weight in some cases being classified by letter. For example, $\frac{5}{8}$-in. pipe, distinguished by the letter A, weighs $2\frac{1}{2}$ lb. per ft., while pipe marked A. A. and A. A. A. weighs $2\frac{3}{4}$ and $3\frac{1}{2}$ lb. per ft. respectively. I believe the simplest and best method to adopt is to purchase pipe stating the inside diameter and weight per foot. My reason for this recommendation is that I have talked with several water-works men who purchase lead pipe under the letter plan. Upon drawing their attention to the pressure that the pipe works under, they immediately realize that the pipe is too light to give long service under heavy pressure. On 1-in. service pipe (cement-lined) we use a $\frac{3}{4}$-in. tap with standard iron-pipe thread and a $\frac{3}{4}$-in. lead goose-neck 18-in. long, weighing 5 lb. per ft. On $1\frac{1}{4}$-in. service we use 1-in., 6-lb. lead pipe. On 2-in. service we employ $1\frac{1}{4}$-in. lead pipe, weighing 9 lb. per ft. in a goose neck 2 ft. long. Sweat joints are made with a blow torch and will stand any ordinary pressure. Leaks become negligible with this practice. Most of the lead connections are made up in our shop during the winter months by our service foremen who are plumbers. A 1-in. hexagonal nipple is fastened to the tail piece of the goose neck, the other end being connected to a lead-lined coupling attached to the cement-lined pipe. By this method a perfect bond is obtained in the fittings throughout the entire length of service to the meter, and galvanic action is reduced.

This type of service pipe is employed by many cities and towns today, and under favorable soil conditions and with no electrolytic action it makes a practically perfect service. Some of the departments using it claim that services installed sixty years ago are still in use. I ask the new members of this Association who are just breaking into the water-works business that they consider carefully the experiences of the older members who have given time, thought and study to this important subject. It has often been said that the quality of the water is the principal factor in selecting the material to be used. This is true to some extent, but cement-lined wrought-iron pipe can be used with all kinds of water with good results.

We have several long cast-iron services 2 in. in diameter. During the past year complaints of poor pressure have been coming into the office. On investigation we find the pipe clogged and tubercles much in evidence. To save the water taker the expense of laying a new line, the service is dug at the corporation cock and a street ribbon band pushed through the pipe as far as possible. The same operation is then carried on from the cellar on the pressure side of the meter. The silt is removed from the pipe while

flushing and the flow of water is improved. By cleaning the pipe in this way, the owner is saved the cost of a new service. In my judgment it is poor business to install unlined cast-iron pipe in small sizes for service work.

MR. ESTY. Would you advise using cast-iron pipe for services if it was lined with cement?

MR. HEFFERNAN. I would.

HENRY T. GIDLEY.* I do not think that there is any one kind of service pipe which is ideal for all kinds of water. The quality of the water must be taken into consideration. I have not had experience with cement pipes, but I can imagine that there are different effects on cement linings by different kinds of water. Our water is rather hard and has a corrosive effect; but you can take your hand and rub over the piece removed by tapping cast-iron pipe that has no lining, and has been in service for thirty years, and you will find the lining just as good as it was the day the pipe was put in service. We may be rather archaic in sticking to lead services. We use a good heavy service employing pipe weighing 4 lb. per ft. We use a cup joint made at the shop and we do not have much trouble. Our supply is ground water. The small towns to the east of us,— Mattapoisett, Marion, and Wareham, have similar supplies.

We have heard a lot about copper pipe. It looks very good, but we have not tried it ourselves. At Marion, the second town to the east of us, which has a water similar to ours, a whole house was piped with copper tubing and while it was easy to put in and twist around in any way needed the fixtures were stained green when the water was turned on. It does not look as if copper tubing was a satisfactory pipe for our kind of water.

MR. ANTHONY. We have been using tubing in Augusta since the spring of 1927, and I have yet to find a single flaw in it. To determine how it would stand corrosive action in the soil, I took a short piece and buried it in cinders in the shop yard. It stayed there two years. When I took it out, it showed a little corrosive covering on the outside. This we scraped down with a knife, and the pipe was found to be as bright and clean as the day it was buried. We recently had occasion to increase the size of a main in the street in which the first copper-tubing service in Augusta was laid. When changing the service from the old to the new line we saved a piece of the tubing which had been in active service since July 17, 1927. There was a little green coating on the under side but no corrosion on the upper side, and the inside was perfectly clean and bright after nearly 5 years of use.

A little later I removed a hot-water coil from my furnace. This coil had been practically buried in fire for over a full heating season, which in Maine is about 10 months, and, after buffing on a wire wheel, it could not be distinguished from new pipe. The coil was removed not because of failure, but because I moved to another house.

*Superintendent of Water Works, Fairhaven, Mass.

W. C. HAWLEY.* We have been using copper tubing for six or eight years with entire satisfaction. We have had no trouble with discoloring of fixtures. However, we find that we have to be careful what copper pipe we buy, and we go over our specifications carefully, and inspect the pipe thoroughly.

MR. HEFFERNAN. In the *Master Plumbers' Journal*† a paper read by Professor George E. Russell, "The Relation Between Pressure and Discharge at Plumbing Fixtures," includes the following statement. "The fact has often been brought to my attention that a widespread misunderstanding exists in the plumbing trade as to the relation which pressure bears to the rate of discharge at a fixture; and, since adequate rates of discharge must be provided for in the layout of the piping, it is absolutely necessary that at least a certain minimum of knowledge be had of the pressure-discharge relation."

The failure of water departments and master plumbers to accept this statement and equip themselves with the required knowledge has resulted in past years in a waste of materials running into millions of dollars. That means this: In certain cities and towns, the water department lays the service pipe to the property line, sometimes to the curb; then the plumber comes along and lays the pipe from that point to the cellar. I believe that to be an awful mistake, as the water department is best qualified to judge what material is to be used to give long service. When application is made at our office for a new service the following information is asked for: set-back from street, number of bathrooms, flushometer valve to be used? With this information the Superintendent can say, "You should have under such conditions such a size of pipe and meter."

HERBERT C. CROWELL.‡ I agree with Mr. Heffernan, and I think he is probably right in regard to conferring with architects and owners of property. But he says he tries to have them put in the proper size service and meter. We do not do that in Haverhill. They put in what we tell them to.

This question of service pipe has been under discussion in this Association for a good many years. I heard it in Portland fifteen years ago, and I have heard it a good many times since. In the old days, thirty-five or forty years ago, we used to run our own service pipes. Since those days there has been considerable improvement, in cement-lined pipe especially, and today there are many makes of service pipes in the market. In Haverhill for the past seventy-five years we have used lead pipe up to 1-in. in diameter. Beyond that we use cement-lined pipe, galvanized-iron pipe, or whatever we think is best. I have seen cement pipe that had been underground for twenty years in very good condition; I have seen it in ten years in very poor condition. It depends upon the nature of the soil.

I do not think that any one pipe can be made to serve all cases. I

*Superintendent, Pennsylvania Water Co., Wilkinsburg, Pa.
†February 25 and 26, 1931.
‡Superintendent of Water Works, Haverhill, Mass.

think every man has to settle in his own mind, from his experience and knowledge, what pipe he will use. Personally I like a lead pipe up to 1-in. in size. We have taken out 1-in. lead services which have been in for forty or fifty years, and outside of the fact that in those days the pipe was lighter, it was in good condition. Today we use heavier lead pipe, $3\frac{1}{2}$ lb. per ft. for $\frac{5}{8}$-in. pipe and 4 lb. per ft. for $\frac{3}{4}$-in. pipe. While I think this is a question well worth talking about I feel at the same time that it is a question that each one of us must settle for himself.

ARE FURTHER STUDIES NEEDED ON THE RELATION OF FORESTS TO WATER SUPPLY IN NEW ENGLAND?

BY C. EDWARD BEHRE.*

[*Read November 18, 1931.*]

In reviewing the proceedings of the New England Water Works Association, the American Society of Civil Engineers, and other organizations interested in hydrology one finds that at various times in the past considerable attention has been given to discussion of the relation of forests to floods, stream flow, erosion, and water supply. A large part of these discussions consisted of conclusions drawn from empirical observations of the flow of certain streams or from analogy with studies made under widely different climatic, topographic, or soil conditions. Many of the arguments advanced were based on theoretical considerations which never have been subjected to measurement or experimental proof.

One is especially impressed with the fact that, although stream flow records in New England have been accumulated over a long period of years, very little attempt has been made to study the influence of forests and other forms of vegetation on the stream flow.

In discussing this subject it is not my intention to present any preconceived argument on the rôle of forests in relation to stream flow and water supply, but rather to seek discussion concerning the nature of the problem in New England. I wish to tell of a proposal for a nation-wide program of erosion-stream-flow research at the regional forest experiment stations of the U. S. Department of Agriculture and to secure guidance in the application of this program to the Northeast. I would like discussion not so much on theory as on phases of the problem in need of study.

A National Program of Erosion-Stream-Flow Research. During the past few years there has been a remarkably widespread and growing public interest in national problems involving water resources. This has been in no small measure the result of the Mississippi flood of 1927. Control of the Mississippi is a problem that involves to a large extent questions of land use in many states. A major part of the attention of commissions appointed to study the situation has been directed toward construction of levees and other engineering works along the main river channel rather than toward amelioration of conditions along the streams feeding the main river. This striving for a cure without removing the cause has repeatedly resulted in failure, and each failure has made necessary new construction on an ever-increasing scale. Since the last flood, increasing interest has been shown in means of lessening the silt load of the river by the prevention of erosion in various parts of the Mississippi basin.

*Director, Northeastern Forest Experiment Station, Amherst, Mass.

In California, water resource problems have also been very much in the public eye in recent years. In certain sections of California the ability to secure water is the most important question before the people. Water development for growing centers of population in the cities has sometimes interfered with water supplies for agricultural purposes, and the whole future of southern California is tied up in the problem of water.

In the Piedmont region of the Southern Appalachians, public interest in problems of this sort has also become keen because of the realization that the decline in agriculture in many sections is the result of loss of the fertile topsoil through unchecked sheet erosion in previous decades.

Growing realization of the importance of stream flow and erosion problems in all sections of the country has led to increasing demands for investigations in this field.

At the present time facilities for such work are rather limited in scope. The Forest Service can handle a certain number of water-resource projects at the regional forest experiment stations under the McSweeney-McNary Forest Research Act of 1928, but this will have to be on a small scale unless special appropriations are made each year under pressure as happened in the last Congress.

The Bureau of Chemistry and Soils is developing a program of erosion studies on a large scale. This program provides for a number of field stations devoted to agricultural phases of the erosion problem. Attention will be restricted to methods of cultivation to reduce erosion, methods of terracing, etc., with only secondary consideration of the effect of forests in preventing erosion of non-agricultural lands or in checking erosion on lands no longer profitable for agriculture.

The urgency of a more specific and comprehensive program of erosion-stream-flow research from the standpoint of forest influences is emphasized by the large number of proposals for flood control, irrigation, improvement of navigation, and development of water supplies or power which are being planned largely or wholly without regard to the possible relation of forest or range-cover to stream flow and erosion. On the Mississippi alone, flood control and navigation programs total approximately $350-000 000. In the last Congress several bills involving expenditures running as high as $750 000 000 were introduced, and practically all dealt with engineering works for control, without further study to establish methods of eliminating the cause.

A year ago, during the Senate hearings on the Agricultural Appropriation Bill, the Department of Agriculture was requested to submit a program for erosion-stream-flow research on forest and range lands. A hasty survey of the situation was made, and a statement outlining the outstanding problems in each region was prepared.

Based largely on this program, Congressman Scott Leavitt of Montana introduced an amendment to the McSweeney-McNary Forest Research Act during the closing days of the last Congress. The Leavitt Amendment

authorizes an annual expenditure of $500 000 for a nation-wide study of forests in relation to erosion-stream-flow and water supplies. The amendment sets up the program but carries no appropriation. Money will have to be secured later for each region and each project to be studied. Each project will have to justify itself, but the enabling legislation proposed will serve more or less as an index of the wishes of the people.

The question in which we are particularly interested here is, "How should the Northeast fit into this program?" In this section of the country interest will center chiefly on problems of water supply for municipal use and for power. The water-resource question is of considerable importance to the Northeast because of the dense population and large number of cities which are dependent in large measure on surface drainage for their water supplies. The overwhelming importance of surface drainage as a source of supply is shown by the fact that 42 out of the 68 cities in the United States with populations over 100 000 in 1920 secured their water in this way.

In a recent article in the *Scientific Monthly*, Professor R. M. Brown of the Rhode Island College of Education, says of New England: "The great problem that remains is the quantity of water in the face of growing populations," and further that the immediate need is for study of the coördination of requirements of all communities over extensive areas.

The Water-supply Situation in the Northeast. Before discussing possible research in this field we should consider certain aspects of the water-supply situation in the Northeast from the standpoint of present trends and probable future needs. It would be presumptuous on my part to attempt to analyze the water-supply situation in New England for men who are so much more intimately associated with the problems involved. But I shall make some statements without any claim of authority with the idea of provoking discussion.

In general, rainfall in New England is plentiful enough and regular enough to create the feeling that water supplies may always be easily and adequately developed. But the dry years of 1929 and 1930 have emphasized the need for more adequate regional planning in this respect. The seriousness of the water-supply question in this section was brought home to us when public restrictions on the use of water became necessary. According to Brown: "In many cities the supply is adequate if rains are fairly regular, but a serious deficiency of water is the experience of too many communities when a long dry spell is experienced.

"Today in the eastern populated district, towns and cities are competing for drainage areas, and protection for present supply and particularly for future needs is a new problem that must be considered. No adequate estimate of future requirements has been made, and no great regulations covering the rights of other communities have been formulated."

From this it might be inferred,— and other students of the situation have so stated,— that water is likely to be the limiting factor in future

community development in the densely settled districts of southern New England and New York. Perhaps all available wild lands may be in demand for watershed purposes. Some idea as to how closely water resources are being utilized may be obtained from the following crude calculation.

Fairly reliable figures on the total forest areas of each state may be taken as equivalent to the available watershed area. Assuming that each square mile of watershed will supply 5 000* people with water, we can compute the potential population as limited by this factor. If we compare the present population to this figure we get a percentage of full utilization. On this basis southern New England, as shown in the accompanying table, is already using about one-sixth of its potential water supply. It is of course impossible to obtain full utilization, and in many sections the condition already exists where additional supplies can only be obtained by invading territory which might be tributary to and needed by other communities. It is, therefore, important that the development of water for any community should be correlated with probable demands of other communities.

FOREST AREA AND WATERSHED UTILIZATION IN NEW ENGLAND AND NEW YORK.

	Total Forest Area. Sq. Miles.	Potential Population @ 5 000 per sq. mile of Watershed. Millions.	Present Population 1930. Millions.	Per cent. of full Utilization 1930.
Maine	22 700	113.5	0.8	0.7
N. H.	6 930	34.6	0.5	1.5
Vt.	5 050	25.2	0.4	1.6
Mass.	5 090	25.5	4.2	16
Conn.	2 470	12.3	1.6	13
R. I.	436	2.2	0.7	30
N. Y.	18 750	93.8	12.6	13
Southern New England	7 996	40.0	6.5	16

Inadequacy of surface drainage in any locality raises the question of utilizing the flow of larger rivers by purification. In the article already cited Brown says: "The process of cleansing polluted water has reached so high a degree of perfection that almost any raw water may be rendered clear, palatable, and safe." If this is so, it would appear that the question of developing new surface supplies, as opposed to purifying polluted river waters, is largely one of relative cost. The fact that pure surface waters are still favored and are being developed almost without consideration of cost indicates, however, that the problem is not quite so simple and that

*EDITOR'S NOTE: New England experience indicates that average watersheds can be developed economically to yield 750 000 gal. per sq. mile per day.

studies of factors affecting surface supplies may still be of considerable interest.

The factor of cost in the development of water supplies is of increasing importance as scarcity of readily accessible supplies makes itself felt. Full utilization of any watershed may be secured by building storage reservoirs large enough to hold all the rain which may run off that watershed. On any given catchment area there is a point beyond which the added cost of development does not result in commensurate increase in supply. To hold all the water which comes down in times of high water involves a large investment which is not productive during the remainder of the year. Consequently it is seldom economical to attempt to store all the water from the watershed. Consideration of the influence of forests or other forms of vegetative cover is important here because if, through control of the vegetation, the stream flow can be made more uniform and peaks of floods reduced, a larger proportion of the water yield may be utilized with a given storage capacity.

Perhaps of greater importance are considerations of seasons of minimum stages of stream flow. Unless all the water which is yielded by a watershed can be stored, the adequacy of a given development is dependent entirely on the available supply in dry times. If the flow during such times is less than the demand of the population to be served, new supplies must be developed. If the available supply during dry times can be favorably influenced even by a very small percentage through control of the vegetative cover of the catchment area, the necessity of seeking new supplies may be eliminated. Forests probably give the most effective cover because of their tendency to equalize the flow of streams. This involves not only a reduction of the crest of floods but a raising of low stages during drought.

Stability of flow of streams is also of fundamental importance in connection with power development since the generating capacity of any water-power project must be largely determined by the ability to maintain production during low-water stages.

What Can Be Done By Research? With these comments on the water-supply situation in New England we may turn to a consideration of what may be done by research.

The study of water resources of extensive areas with the idea of coördinating the needs of all communities involved and planning the most effective distribution of surface waters to the various communities is primarily a task for water-supply engineers. But such a study would have to consider how far the use of land for watersheds might interfere or restrict normal use for other purposes such as recreation, hunting, fishing and summer homes. Coördination of the use of land for water supplies with other uses calls for a broader viewpoint. Although in the past it has been customary to think that the primary uses of wild lands were for production of lumber and other forest products and for the protection of the headwaters

of navigable streams or water supplies, it is interesting to note that Professor G. F. Warren of Cornell, one of our foremost land economists, ranks forest use values about as follows: recreation, scenery, hunting and fishing, stream flow, city water, and finally, lumber and other forest products.

This emphasis on the intangible, esthetic values in the use of wild lands is without doubt expressive of the trend of the times. It indicates clearly that in the planning and developing water supplies, other uses of the land compatible with protection of the water must be worked out and encouraged. It is significant that the maintenance of forests is generally considered conducive to optimum results for all of the uses named.

Research may work out more clearly the probable trends in the need for land for various purposes. It may assist in coördinating and integrating these uses most effectively and should lay the basis for sound public and private policies in respect to land use.

In regard to the more specific problems concerning the relation of forests to water supplies the first need is for experiments to develop adequate methods of recording water yields under different types of vegetative cover on various kinds of soil. With a technique of measurement worked out, research should then aim to establish the effect of vegetative cover of various sorts on the quantity, regularity, and quality of stream flow.

It is important to know whether forest growth is superior to grass or brush for watershed purposes. The effect of changes in vegetation on permeability of the soil should be studied. Have past cutting and fires materially altered run-off conditions over large areas? The effect of various types of vegetative cover on erosion and color of water may be worked out. Experimental evidence should be accumulated to determine what the effect of various types of vegetation is on water loss through transpiration and evaporation.

The question is often raised as to the relative value of coniferous and hardwood forest cover. Along streams and reservoir margins, coniferous trees are undoubtedly preferable, because the accumulation of hardwood leaves in the water is undesirable, but whether there is any choice between these types of growth for general watershed cover is not so clear. The facts may be established by intensive studies.

If the former showing of seasonal reduction of flow of the Merrimack River and other streams with progress of lumbering is correct, a reverse trend should be shown in recent decades. The large volume of data on stream flow which has been accumulated in New England should be given critical study in a program of this sort in order to establish any correlation with changes in character of vegetation which may be indicated. Study of these records will doubtless afford leads to interesting problems on specific watersheds which deserve more intensive investigation.

I trust this sketchy presentation of the subject will open the way for constructive discussion.

Discussion.

Harold O. Cook.* There is not much that I can add to Mr. Behre's exposition of the study and research needed in the Northeast. In 1925, in connection with forestry work, I had occasion to go over many of the watersheds of Massachusetts and became impressed with the magnitude of the problem of water for domestic use. The average layman does not recognize water as a product of the land. He thinks it comes out of the clouds. But you and I know that practically all the water we are able to use either comes off or out of the land, and the supply of water, therefore, is one of the important factors of land use, especially in southern New England. Under Massachusetts conditions for example, counting in the new Swift River project of the Metropolitan District Commission, we will have used somewhere between 900 and 1 000 square miles of the land area for water supply purposes. That represents over 12 per cent. of the total area of the state, or about 20 per cent. of its forest area. You can see, therefore, that municipal water supply is a very important factor in the land use of Massachusetts.

As Mr. Behre has said, it is fortunate, in so far as forestry and water supply are concerned, that these two uses of the land seem to go hand in hand. There are other important forms of land use of importance which are not always compatible with water supply. Such, for example, is the use of land for factories and cities. Even the use of land for agriculture or recreation is sometimes not a suitable complement of water supply.

In times past foresters, along with others, have made some unsupported claims in regard to the effect of forests on water. Much of our information was taken from European literature, because we had not had time in this country to carry on the necessary research to find out what the facts are here. As Mr. Behre has pointed out, there is a dearth of scientific information on the relation of forests to stream flow, and it is to make up for this lack of information that a countrywide research program is to be taken up at this time. After talking it over with Mr. Behre I am sure that great assistance will be given the water-supply problems of New England, including not only municipal water supply but also water-power which is of such importance in northern New England.

Caleb M. Saville.† So far as the writer is concerned, there is no negative side to the question which is the subject for discussion so ably presented by Mr. Behre.

Further studies are needed on the relation of forests to waters in the Northeast, and the writer hopes that the New England Water Works Association will take up this matter in its broad sense by the raising of a Committee on Care and Protection of Water Supply Watersheds, who will consider the subject carefully and submit progress reports from time to time for discussion. To such a Committee, such questions can be referred

*Massachusetts State Forester.
†Chief Engineer, Water Bureau, Metropolitan District, Hartford, Conn.

as are raised in Mr. Behre's paper, and, after due consideration, reported back to this Association for its information and action.

While the writer is in full accord with the general argument of the paper, some matters are of too much importance to be acted upon without careful consideration. All who have given this subject constructive thought are convinced of the protective value of forests (1) in reducing erosion by binding the soil with roots and by covering the surface with humus and debris, and (2) in exerting a modifying effect on the flow of streams by lessening evaporation losses due to shading of ground surfaces and by the sponge-like effect of the ground cover in slowing down run-off. Floods on a watershed are productive of great loss of water, and proper watershed operation is the equivalent of enlarged storage capacity.

Any slowing down of the run-off after a heavy and continuous rain allows the water to percolate into the ground, whence it reappears later in the form of springs. The value of this is two-fold; conservation of water, with increased yield, and improvement in the quality of water by underground storage and natural filtration.

So far as the relation of forests to rainfall is concerned, the best thought of today seems to be that there is no appreciable effect, if there is any at all. B. E. Fernow,* says: "No influence upon general climate which depends upon cosmic causes can, in reason, be expected from a forest cover."

In his report† on the improvement of the Merrimack River between Haverhill and Lowell, Lieutenant-Colonel Edward Burr,† Corps of Engineers, U.S.A., submitted a very interesting report on the influence of forests on the run-off of the Merrimack River Basin. After a most painstaking study of this question, Burr states (p. 10): "To the writer, it seems clear that nothing in the following facts as a whole gives any support to the general popular belief that deforestation has exerted a harmful, and reforestation, to the extent of 25 per cent. of the entire area, has exerted a beneficial effect upon stream flow, in so far as concerns the Merrimack Basin." In commenting upon this statement, Burr remarks that "the characteristics of stream flow are so largely, if not entirely, dependent upon precipitation modified by temperature and other climatic influences, that any analysis of the former must be based upon a substantial elimination of the variations in the latter for determination of effect," and also that only from long-term records, *i.e.*, periods of over 60 years, can reliable deductions be made. Burr states that his "analysis of long-time records in Southeastern New England shows no decrease in precipitation with progressive deforestation," and that "it seems safe to say that changes in precipitation have moved entirely independently of forest conditions."

In 1909, the Forest Service of the U. S. Department of Agriculture planned a comprehensive study of the effect of forest cover on stream flow. This experiment was carried out on two areas of about 200 acres each at

*B. E. Fernow, Chief of Forestry Div., U. S. Dept. Agri. *Bulletin* 7, p. 13.
†Document 9, House Record, 62nd Cong., 1st Session.

Wagon Wheel Gap, Colorado, under the direct supervision of officials of the Forestry and Meteorological Service, assisted by government geologists.

Prior to this experiment, the only other study at all comparable with it, was that of Dr. Arnold Engler of the Swiss Forest Service near Elemental, Switzerland, with observations lasting over a period of 15 years.

In the American experiment, two neighboring areas were selected, as similar as possible in location, elevation, and physical and topographical characteristics. After a period of observation of rainfall and run-off, extending over about eight years, with both areas in natural condition of forest cover, the first stage of the experiment was closed, and one of the areas (B) was denuded of its forest cover, while the other area (A) was left untouched during the remainder of the experiment. The experiment was then continued for seven years, with simultaneous observations of meteorological and stream-flow conditions.

In the years,* before area B was deforested the average annual precipitation was 21.03 in. with run-off of 6.08 in. from area A and 6.18 in. from area B. During the years following the denuding of area B, the average annual rainfall was 21.16 in., and the run-off 6.3 in. from area A and 7.26 in. from area B, showing an excess of 0.96 in. from the denuded area B over the forested area A.

While no attempt is made, as the result of this experiment by the department, to prove or disprove a theory, the facts are fully stated, and it is possible to draw very valuable lessons from them. The discussion states (p. 83) that it is probable that "interception by tree covers is a large factor in evaporation losses during the winter." It may be inferred that this cause was considered as a possible reason for a large part of the excess run-off from the denuded area over that yielded by the area A with its natural cover. Be these facts as they may, the point which it is desired to emphasize is that yield of watersheds is dependent upon many factors, and that, while forest cover may exercise considerable influence, it may not even be a major influence, although one well worthy of intensive study in connection with water-supply development.

It is interesting to note the agreement of the facts here reported independently by well qualified observers, the Merrimack investigation by an engineer, Colonel Burr, the Wagon Wheel study, by qualified forestry and Weather Bureau scientists. In the last clause in the report of the Wagon Wheel Gap study, it is stated: "From the evidence of this study, it is estimated that in a locality where the normal ratio of high to low stages is more than 25 to 1, with moderate protective cover, the probabilities are that the low stages would be made still lower by removing that protection."

Starting with the water that falls on the ground (precipitation), part appears as stream flow or yield and part disappears, so far as observation

Monthly Weather Review, March 1928, p. 82.

is concerned. In an ordinary southern New England watershed, with no appreciable water surface and little swamp land, about 53 per cent. of the rainfall may appear as run-off in the streams, leaving 47 per cent. unaccounted for on land areas, about 20.5 in. For water surfaces, the results of the Fitzgerald experiments give a loss of about 39.2 in. or 89.7 per cent. of an average rainfall of 43.56 in.

The portion of the rainfall not appearing as rainfall, is generally called evaporation, including under that name, some water irretrievably lost by deep percolation, use of water by vegetation through transpiration, or the evaporation of water from the stomata of leaf surfaces, and by interception by foliage. These last two are the only parts of the total which actually should be called evaporation and account for the greater part of the losses. The transpiration of deep-rooted vegetation is less fluctuating than that from shallow-rooted, and, in dry season, the former draws most heavily upon ground storage.

For estimating water losses by transpiration, Meyer* gives the following table:

	Inches per year.
Grass, grains and agricultural crops	9 to 10
Deciduous trees	8 to 12
Small trees and brush	6 to 8
Coniferous trees	4 to 6

The experiments of the Kansas State Board of Agriculture shows a use of water by fir trees about one-sixth that of grasses and about half as much as for oak trees.

Additional to the use of water by vegetation is the amount of water falling upon tree crowns and never reaching the ground because of evaporation-interception. The amount of rainfall lost to stream flow by this means varies with the intensity and duration of the rainfall. Horton† reports 70 per cent. so lost in light showers and 24 per cent. in heavy rainfall. On the other hand, German observations‡ indicate the following ratios of evaporation, taking that on bare ground as 1.0: grainfields 0.8; grass land 0.7; light forests 0.6 and dense woods from 0.2 to 0.4.

In the matter of a national program, I am not enthusiastic over cooperation between state and national governmental agencies, as I believe that, as a general proposition, the state buys experience while the national government gets the money, a good part of which is expended for national bureaucratic expansion. I am convinced that there is necessity for such investigations as are proposed, but I feel as strongly that the end can be better attained by coöperation between independent state and national agencies rather than by partnership.

Mr. Behre gives a very well-put syllabus of the prime matter as affecting New England water-supply conditions, and I shall be glad if

Elements of Hydrology, p. 281.
†*Monthly Weather Review*, Sept. 1919.
‡*Bulletin* 7, Forestry Div. U. S. Dept. Agriculture.

something constructive can come from it. Included is a most pertinent question for perhaps the near future. The recent controversies, Connecticut–Massachusetts and New Jersey–New York, over water-supply diversion from interstate streams, is a very broad hint of coming questions that must be solved for the benefit of the public. This is a matter in which this Association should be very much interested.

The author particularly calls attention to the development of water supplies as an essential concomitant of community life and well being. Of paramount importance to the subject of this division is the desirability of pure surface-supplies as opposed to purification of polluted waters. Time is not available,— nor is this the place,— for discussion of this subject which has ardent advocates on both sides: On the one hand, the theorist and near scientist, who affects to believe that reclaimed waters are just as good or better than naturally pure water, because by perfect laboratory technique, he is able to turn out a harmless product; on the other hand, is the experienced water-supply specialist, who knows that both art and science, in the present state of human development, are not automatically trustworthy, and that, when dealing with community health and life, it is better to be safe than sorry. No surgical operation was ever not a complete success. If the patient dies, it is the fault of the attendant doctor, the nurse or the weather.

In the Connecticut–Massachusetts diversion case, the Master said: "Our governments, in the long run, are controlled by public opinion. And while an expert on water, acting in a strictly professional capacity, may say that he will disregard public opinion, municipal and other governments cannot take that stand. The Courts, it seems to me, cannot close their eyes to the necessities imposed by public opinion on governments."

After a considerable study of water-supply conditions in the Northeastern United States and in Southern New England especially, I am convinced that there is plenty of good, natural water for domestic supply for centuries to come, without recourse to polluted streams.

While I am in full accord with any reasonable endeavor to clean up the streams and prevent unsightly pollution, I am firmly convinced that the attempt to restore pristine purity or even an approach to that condition is neither desirable nor practical. The streams of this country are its natural drainage channels. New England's position in the world came from its industries, not from its attractiveness as a recreational center. In order to hold that position, we must not kill the goose that laid the golden eggs. Regulation is necessary as the country grows, but not prohibition, at least in stream control.

It is neither good business nor good health control to force people to drink the purified carrier of community wastes in order that sport and recreation may be served.

As to relative costs, there are some things that are without price — "All that a man hath will he give for his life." If no water is available except

purified sewage, that is what a man must drink. If it is merely a question of cost and this a free country, and if the community is satisfied with inferior water because it costs less, that is its affair up to the point where public health is affected.

Communities themselves, and neither scientists nor psuedo-scientists, are competent to say whether or not the cost of storage works exceeds the value of the water stored. Vegetation on a watershed without doubt influences total yield, but not to the extent often claimed. It is probably a fact that increase of a few per cent. in run-off may be obtained by proper forestry control and that this may obviate expensive development for safeguarding water supply against an infrequent dry period.

There can be no logical argument against the development of water resources for community enjoyment, but this should be done by local government, rather than by state organization. The people benefited and taxed for support of the works, rather than state organization subservient to political control should have full and unhampered power over so vital a matter as a public water supply, and a general legislative body is a much safer board of appeal than a state board whose members are appointed and whose organization is controlled by political exigency.

In the matter of research, all of the author's suggestions are good from the general standpoint, but for water-supply purposes, it is desirable to rearrange the list proposed by Professor Warren. For our work, city water-supply comes first, and all the others follow. Some that are first in his list, should be very far down the line, from a water-supply standpoint. Recreation, hunting, fishing and even summer homes are not such essential elements in community life as is a pure water supply. Comparatively few in the community avail themselves of these opportunities, while all in the community suffer if the water supply is foul.

A discussion of the best character of forest cover on water-supply areas is essentially a matter for consideration of a Committee from this Association.

When the U. S. Public Health Service, in its monograph* on "Sewage Polluted Surface Waters as a Source of Water Supply," makes the statement "that pollution of the sources of many surface supplies has increased with such rapidity that questions have arisen as to the possibility of a failure of existing safeguards, both natural and artificial to afford an adequate degree of protection to such supplies," and Sir Alexander Houston, probably the most eminent sanitary expert in the world today, in his last report† on water supply for the city of London, warning against too implicit dependence upon sterilization, says: "We must still seek virgin sources of water supply, still retain and maintain, as far as this is reasonably practicable, the old established armory of defence," is it reasonable for water-supply engineers to look with equanimity on the proposition of seek-

*Public Health Reports, Vol. 43 No. 24, June 15, 1928, p. 1 499.
†25th Annual Report Metropolitan Water Board, London, England, p. 3.

ing future water supplies in filthy streams, in order that comparatively few out of the whole population may enjoy wild life, with hunting, fishing, recreation and a few summer homes occupied during a few months at the most? "If that be treason, make the most of it."

As to foreign practice, an eminent English water-supply engineer, in discussing the matter of "afforestation of catchment areas,"* recently said, "Although in the past, it has not always been recognized that ownership of gathering grounds by the water authority is necessary, the author is strongly of the opinion that it is essential and practice is now tending in that direction."

In pursuance of the belief that it is sound policy for a public water-supply authority to own its gathering grounds as far as practicable, the Metropolitan District of Hartford, Conn., leading up to development of its proposed new supply, has or will acquire about 10 500 acres in the towns of Barkhamsted, Hartland and Granville, which, with ownership of the state authorities in 6 000 acres of forest land, gives control of about 80 per cent. of the watershed in Connecticut and of 50 per cent. of the total watershed in Connecticut and Massachusetts. In developing this supply, the Metropolitan District of Hartford County has undertaken to safeguard the supply of all the municipalities within 20 miles' radius of Hartford. In the existing water-supply systems, the Metropolitan District owns 4 500 acres in the vicinity of its Nepaug Reservoir and 2 500 acres in the vicinity of its West Hartford reservoirs.

Harris A. Reynolds.† One of the best statements that I ever heard about forests and stream flow came from the Father of Forestry in Pennsylvania, Dr. J. T. Rothrock. Dr. Rothrock I suppose did more for the establishment of over a million acres of forest in Pennsylvania than any other man. In discussing this matter one time he said: "In this question of water supply, I believe in the hickory-stick philosophy. Go out in the winter time when the ground is frozen and cut a hickory stick and sharpen it. Then go out in an open field and try to poke the stick into the soil. You will not make any impression. But go into the forest and you will find that you can poke the stick down as far as you want to. It follows that when the rains come during the winter, the water can't get through the frozen ground of the fields and must run off, whereas in the forest the water will get underneath the leaves and the ground will absorb it."

C. E. Kendall.‡ Congressman Davey some five or six years ago stated that the ordinary well developed hardwood tree would consume from the first of April to the first of September 500 barrels of water. Miss Julia Allen Rogers, a noted student of Nature, states that the ordinarily developed hardwood tree would transpire 28 000 gallons of water during the growing season. That means 185 gallons of water per day. Dr. Thom of

Trans. Inst. Water Engineers, Vol. XXX, 1925.
†Secretary, Massachusetts Forestry Association.
‡Water Commissioner, Winchester, Mass.

Washington has said that the average tree will transpire one barrel of water per day.

It seems to us in Winchester that we ought to conserve that water by the changing of the hardwood to the evergreen trees. We have set out 340 000 trees upon our watershed within the last twelve or thirteen years.

From personal experience I can state that wherever we can have one inch in depth of evergreen foliage upon the ground one can take a sharp-pointed chisel and all during the winter, in the coldest of weather, one will find that there is no frost in the ground. That is a wonderful asset as it also prevents evaporation to a great extent. This leads us to believe that when we have the 400 acres of our land covered with the dense shade of evergreens, we shall have a greater supply of water than we now have. One of our former state foresters said that it requires 50 gallons of water to grow one pound of hardwood foliage but that it takes only 43 pounds, or 5 gallons of water, to grow one pound of the foliage upon evergreen trees.

C. R. TILLOTSON.* My observation around New England is that here our forests are probably not of great importance in so far as erosion is concerned. We know they are important in some parts of the country, such as the southern Appalachians, where the soil is eroded. But I do not think there is any question that a cover of some kind is desirable. Whether forests are the best cover or not is what we want to learn. Forests do have an influence upon the quality of the water and upon its quantity and the regulation of stream flow. I do not see how there can be much question about that. Anybody who has traveled in the spring of the year when the snow is all gone from the pastures and the open land but is still to be found in the woods, must be convinced that the woods do have some influence upon the run-off. Just how much, and what the other influences are, we want to know.

*District Inspector, U. S. Forest Service.

WATER WORKS IN CUBA.

BY JOHN F. PIERCE.*

[*Read January 13, 1932.*]

The island of Cuba is long and narrow. Extending from east to west a distance of 730 miles, it is shaped like the arc of a circle. North and south, the width of the island is 130 miles from Practicos Point, at the eastern end of Neuvitas Bay, on the north coast to Mota on the south coast, and 25 miles from Mariel to Majona. The area of Cuba approximates that of the state of Pennsylvania, covering 41 634 square miles.

Topography. The coast line is over 2 000 miles long and has many bays and ports with narrow entrances, such as Bahia Honda, Havana, Matanzas, Isabela de Sagua, Nuevitas, Nipe and Baracoa on the north, Guantanamo, Santiago de Cuba, Manzanillo, Cienfuegos, and Batabano on the south.

As one travels over the island by automobile of American manufacture, by slowly moving express train drawn by oil-burning engines, or slower local train, by gasoline car which has replaced the locomotive on the branch lines, by beach wagon, horseback, or aëroplane, one may observe three groups of mountain ranges separated by two rolling plains. The highest ranges are in the east surrounding Santiago de Cuba, extending from Cape May to Guantanamo. The Sierra Maestra is the principal range. Here are the Pico de Turquiro (elevation 7 900 ft.), the Gran Piedra (4 900 ft.) the Ojo de Toco (3 300 ft.) and the Yunque (2 800 ft.). Proceeding west across the Cauto valley and the flat Province of Camaguey one encounters another group of mountains: the Sierra Morena, west of Sagua La Grande, Bamburaneo and Lamatrambre south of Yaguajay and Jabitonico. In the southern part of Santa Clara Province is a solid mass of mountains, while from the western end of this province to the western end of Matanzas Province is a broad prairie. In the city of Matanzas is the beautiful valley of Yumuri, the mecca of tourists to Havana. Around Havana are three series of hills: the Sierra de Bejucal, the hills of Managua, and those of Candela. The western group of mountains is formed by several ranges named the Sierra de Los Organos in Pinar del Rio Province.

Rivers. There are over 200 rivers on the island. Not more than ten of them can furnish enough water throughout the year for municipal requirements. Usually the sources of these rivers are springs. All of them are in flood during the rainy season but dry up quickly when the tropical sun shines upon them. It is not uncommon to see an ox cart traversing the river bottom in the dry season. The rivers are generally short in length, and their course, as a rule, is normal to the coast. The rivers flowing north

*Civil Engineer, South Weymouth, Mass.

are shorter than those flowing south. The Cauto River alone flows westward a distance of 150 miles at the eastern end of the island.

Close to Havana is the Almandares River, the source of supply for several communities including Marianao (population 40 000), Regla (16-000), and Santiago de Las Vegas (12 000). During the rainy season the river water is pumped through pressure filters before being distributed to the consumers.

A few miles to the south flows the Ariguambo River which is the water supply for San Antonio de Los Banos (population 13 000). Its source is the lake of the same name having a surface area of 6 sq. miles. It is one of the few lakes in Cuba. At the lower end of the town the river disappears into a cavern. The maximum turbidity that has been reported for this water is 90 p.p.m.

At Matanzas there are two rivers of considerable size and volume, but they are not used for public water supplies.

In Oriente Province lies the Rio Yara which supplies the city of Manzanillo (population 22 000). This river has its head waters in the Sierra Maestra and flows for many miles through a flat country before it discharges into the Gulf of Guancanyabo. The soil of this country, which is alluvial in nature, is readily eroded and washes into the river causing a rapid rise in turbidity. It is not uncommon to record a turbidity of 3 000 p.p.m. within a few hours after rain commences to fall on the watershed. A turbidity of 10 500 p.p.m. has been observed.

On the other side of the Sierra Maestra range is the Rio Cauto which the Central Government is planning to use for the future water supply of Santiago de Cuba. To the north of this city flows the San Juan river, the oldest source of supply for the city.

Smaller rivers are the Rio Guanajay, which disappears into the ground after a surface flow of 12 miles; the Rio Jatibonico del Norte which disappears, reappears, and then disappears; the Rio Mayari and Moa which pass through caverns; and the Guaso near Guantanamo.

Geology. Geologically the island is anticlinal in structure, the dip being strongest in the northerly direction. It is the belief of geologists that the island was lifted out of the sea by volcanic action during the Miocene period. The predominant rock is limestone, distinctly stratified. The pre-tertiary sedimentary rocks are covered with diorites, basalts, serpentines, primary and secondary sandstones, and conglomerates.

In conducting the investigations for the future aqueduct of Santiago de Cuba, numerous drill holes were made. Breccia was encountered, but the drillings did not extend deep enough to determine the underlying strata. Earth movements are not uncommon at the eastern end of the island. They are of slight intensity and short duration, therefore not serious in nature.

Ground Water. Ground water is abundant throughout the island, due to the great porosity of the limestone. Some of the ground water appears

in springs and subterranean rivers. Wells are common. In some sections of the country water is available by drilling a well almost anywhere, but there are places where several holes have to be drilled before water can be located. Disappointment may result when the well produces salt water.

Work of U. S. Army. One cannot talk about the water supplies of Cuba without paying tribute to the officers and men of the U. S. Army who were stationed there during the period of American occupation. Their work has become the foundation of many important sanitary structures of today. Consideration was given to the water supplies in every town of importance. This work was not confined to "office" study. Improvements were made to the existing aqueducts of Havana and Santiago de Cuba. Wells were driven in many of the communities. A complete water-supply system was constructed at Guantanamo, and a detailed report accompanied with plans and specifications was made for the improvements to the Santiago de Cuba aqueduct.

Inadequacy of Supplies. One should not gain the impression, however, that an abundant supply of drinkable water exists in every community where there is a water-works system. The opposite is the rule. Past years of drought have vividly demonstrated that in spite of springs and underground rivers, distribution systems become dry.

There are several reasons for the shortage of water. First and foremost is the inability to create artificial storage basins by constructing dams across rivers. The porous limestone becomes a sieve for the stored water to leak through. This has been demonstrated at the Chalons Reservoir of the Santiago de Cuba aqueduct. After the construction of the dam it was discovered that the reservoir would not hold all of the water that it was designed to impound. In locations where it might be possible to hold the water, because of vegetable growth upon the top soil, the underlying rock formation is so brittle that a dam cannot be constructed.

There is, furthermore, the situation in which the town has outgrown its system. As the people become accustomed to aqueduct water the consumption increases. The original system cannot meet the demands. It then becomes necessary to curtail night service to allow a sufficient amount to be collected for the next day's supply. The houses and buildings of better class have tanks upon the roof or below the ground holding several days' supply. When the service is interrupted, or curtailed, water is drawn from storage. When service is renewed the tanks refill. A float valve regulates the height of the water in the tank. At one time, practically all of the buildings of more than two stories and 50 per cent. of the residences in Havana were provided with roof tanks.

Many towns depend upon cisterns as a source of supply. Water collected in this way does not contain mineral salts. Consequently there is a tendency to correct this deficiency by the constant use of medicine containing salts. Other communities depend upon shallow wells, or place in the patio the "tinajon," a large earthen jar, to catch the roof water. Water

peddlers are common in many towns, selling water from carts, kegs, and gasoline cans. To supply one town of 15 000 population, the railroad brings water 25 miles in tank cars.

Rainfall. There is a sharp distinction between the dry and the wet season. At least 75 per cent. of the rainfall occurs between May and October. The dry season is not free from rain, but the storms are of short duration and small intensity. The maximum amount of rainfall occurs in

DRINKING-WATER CART.
This picture was taken in a section of Santiago de Cuba in which there is no "piped" water.

May and September. The heavy rainfall in May is due to the vertical sun's rays passing twice across the island, and the forcing of the south-east on-shore winds by the heavy rains along the southern coast of Pinar del Rio Province. At Havana it is an interesting sight, in the afternoon, to watch the approach of the southern rain storm for several hours before it reaches the city.

During the hurricane season in the fall the rain comes from the south-east. Frequently the eastern end of the island receives a heavy drenching, and occasionally the low lands are inundated. The effects of these storms are noticed in Havana.

The most reliable rainfall observations have been made by the National Observatory at Casa Blanca, across the bay from Havana. Records are also kept by the National Government and by the sugar mills. During the occupation of Santiago de Cuba by the U. S. Army a weather bureau was maintained which reported an annual rainfall for 1899, 1900 and 1901 of 54.78, 59.94, and 57.59 in. respectively.

Two examples of monthly rainfall observations follow:

	Havana. Inches.	Santiago de Cuba. Inches.
January	2.90	1.47
February	1.81	0.87
March	1.89	1.72
April	2.21	3.32
May	4.80	6.45
June	6.36	5.39
July	4.85	2.26
August	5.39	3.58
September	5.82	6.60
October	6.63	7.40
November	3.13	3.61
December	2.40	1.06
Total	48.19	43.73

The total rainfall of 43.73 in. for Santiago de Cuba, compares favorably with the normal of 46 in. A maximum of 94 inches has been reported in this district and a minimum of 14 in.

For computations used in the design of the new aqueduct the Government engineers assumed an annual rainfall of 24.6 in. on the watershed. They estimated that the run-off would equal 20 per cent. of the rainfall or 4.5 in. available for storage. The monthly rainfall expressed as a percentage of the annual rainfall averages about as follows: January 5%, February 6%, March 1%, April 4%, May 17%, June 19%, July 14%, August 6%, September 15%, October 7%, November 3%, and December 3%.

Water Laws. Among the important considerations in developing a utility are the requirements of the law. The first Cuban law I read was enacted by Royal Decree of January 9, 1891 in Madrid in the name of Augusta, son of King Don Alfonso XIII. Its title is "Water Laws For The Island of Cuba." The following articles relate to water for domestic use.

Article 1. The water which flows upon an estate during rains belongs to the owner thereof while it flows thereon. He may, therefore, build or construct within his property reservoirs, dams, cisterns, or tanks in which to retain the same, or employ other proper means, provided it does not injure the public or a third person.

Pluvial waters for the purposes of this law are those which are the immediate result of rainfalls.

Article 2. Pluvial waters which flow through ravines or hollows are of public ownership if their channels are also public property.

Article 3. Municipalities may grant to any person who may request it authority to construct cisterns or tanks for the collection of rain water on public lands situated within the district and under the jurisdiction of said municipality, informing the Governor of the Province of said permission.

Should the decision of the municipality be a negative one, an appeal rests with the Governor of the Province and finally with the Governor-General of the Island whose decision shall be final.

Article 4. The following are public or of public ownership.

1. Waters which rise continuously or intermittently on ground of public ownership.

2. Continuous and intermittent waters of springs and creeks which course through their natural beds.

3. Rivers.

Article 19. Every owner may without restriction dig ordinary wells for the purpose of raising water within his respective estates, even though the waters of his neighbors are reduced thereby. Nevertheless a distance of two meters must be left between wells in towns and 15 meters between new excavations and permanent wells, ponds, springs and canals of neighbors in the country.

Article 20. For the purposes of this law, by ordinary wells are understood those which are dug for the exclusive purpose of supplying the domestic or ordinary requirements of life, and in which no other motive power than man is employed for the raising of the water.

Article 25. The concessions of public lands for the purposes of bringing underground waters to the surface by means of galleries, tunnels, or artesian wells shall be granted by the Administration. . . .

For these workings only such public property may be granted the surface of which has not been granted for another purpose, unless both are compatible.

Article 164. Only when the normal supply of water used by a town does not amount to 50 liters per day per inhabitant, 20 of them being potable, is it permitted to transfer water from that which is destined to other uses, and after proper compensation, the amount needed to make up the above-mentioned quantity.

Article 165. If the town which requires potable water has already a supply of non-potable water, but applicable to other public or domestic uses, there may be made up, after the corresponding compensation, if proper, 20 liters daily of the former for each inhabitant, even though the amount added to that not potable exceeds the 50 liters fixed in the foregoing article.

Article 166. If the water for the supply of a town is taken directly from a river whose supply is owned by one or more proprietors, such of them shall first be compensated who are deprived of legally acquired uses.

Article 167. Private waters cannot be forcibly appropriated for the supply of a town, except when so declared by the Secretary of the Colonies in view of studies made for the purpose and when there are no public waters which can be reasonably applied to the purpose.

Article 168. Notwithstanding the provisions contained in the foregoing articles, the Governor of the Province may, at times of extraordinary drought, and after hearing the Provincial Commission, order the temporary appropriation of the water necessary for the supply of a town, paying the proper compensation to the individuals.

Article 169. When a concession is granted in favor of a private company, and if the town to be supplied should not receive the 20 liters of water per inhabitant per day, mentioned in article 164, the scale of prices to be received for the furnishing of water and laying of pipes shall be fixed in the same concession.

Article 170. The concession referred to in the foregoing article shall be temporary and its duration cannot exceed 99 years. Upon the expiration thereof the works, as well as the pipes, shall become the property of the community of residents, but with the obligation on the part of the municipality to respect the contracts between the company and individuals for the supply of water to residences.

Article 171. It is the duty of the municipal councils to draft the regulations for the administration and distribution of waters in the interior of towns, subject to the general administrative provisions. The preparation of these regulations must always take place prior to the granting of the concessions referred to in the foregoing articles. After the concession has been granted the regulations can be made only by agreement between the municipality and the concessionee. When no agreement can be reached, the Administrative Council of the Island shall be heard, and the Colonial Secretary shall decide.

In general, these regulations are in force on the island today. In addition to them there is the General Law of Public Works dated June 26, 1883. The work of supplying water comes under the jurisdiction of the municipalities. They grant concessions for the furnishing of water to private companies, or individuals, under stipulated conditions and with the approval of the Provincial and Central Government authorities. Finally, the Sanitary Ordinances must be observed. The articles which refer to water follow.

Article 1. The supply of water for the public shall be adequate in quality and quantity as well as in biochemical properties,— that is, water obtained from aqueducts, springs, rivers, wells, reservoirs, cisterns, or other storage receptacles, natural or artificial, — and the means necessary for conserving the purity and healthfulness of drinking water or water for other domestic uses shall be specified.

Article 2. In places in which aqueducts supply potable water to the amount of 150 liters per capita daily as a minimum and in which service is maintained as regulated by the Department of Health and Welfare in accordance with the requirements of the respective Municipal authorities, it shall be obligatory to install independent taps in all houses and buildings and on all floors that are rented separately.

There shall be abolished, in consequence, the use of wells, cisterns, and other storage receptacles of water, unless they are used exclusively by industries with permission of the local Chief of Sanitation and with the approval of the Board of Directors of the Department of Public Health.

It shall be obligatory for the owners of water systems to deliver the water under sufficient pressure for use four meters above street level at the highest elevations of the town during all hours of the day and night.

When necessary the use of filters or other means of water purification, among them chlorination, shall be required.

Article 3. Where the use of wells and cisterns is permitted they must be walled up, in the case of wells, to the level of water in times of drought, and all entrances must be protected by metal screens to render them proof against mosquitoes.

Wells in which the level of the water is more than ten meters from the surface of the ground shall be exempted from protection against mosquitoes.

The drawing of water from wells and cisterns, regardless of their being covered, will not be permitted except by means of a pump in order to avoid, with certainty, the access of mosquitoes to the water.

The walls of wells and cisterns must be distant at least ten meters from any accumulation of sewage matters, organic fertilizer, or other contamination. It is not permissible to cultivate the soil on top of the cover of wells or cisterns.

Article 4. If there is no source of potable water other than a river, the water shall be taken from those portions of the stream in which contamination cannot easily take place. And it shall be prohibited to wash clothes, or discharge refuse and waste waters from alcohol factories, slaughter houses, cemeteries, and other similar places at a level higher than the site at which the water for domestic use is drawn, save in special cases in which the distance is great and then only after permission has been obtained from the Board of Directors of Sanitation.

When wells and springs are used for water-supply purposes they shall be duly protected against all contamination.

Article 5. Any public sale of water shall require the authorization of the local Chief of Sanitation after information of the National Board of Sanitation and Public Welfare. . . . .

The public distribution of drinking water shall not be permitted if the water is not potable and if its analysis has not been satisfactory.

Article 89. On streets through which the water-distribution pipes pass and in which there are drains, or sewers, all of the houses shall be supplied with toilets according to specifications approved by the Administration of Sanitation, to the exclusion of other systems of privies. . . . .

Article 90. Wells, cisterns, tanks, large earthern jars and other water containers shall be constructed in such a manner that they do not impart dampness to rooms, or receive seepage from ditches or privies.

Water Consumption. In estimating water consumption in Cuba, allowance is seldom made for fire demand. American formulas for determining fire-fighting requirements are not applicable. In their place it has been suggested that there be provided a minimum of 156 g.p.m. per 1 000 inhabitants. In the larger cities municipal laws prohibit the use of wooden floors. In these communities a majority of the structures are of fire-resistant construction, being built of limestone or native brick, plaster covered. The floors are of tile, with windows and doors of wood.

The smaller communities have buildings constructed of wood, usually of low height. Every fire is looked upon with suspicion by the authorities, and investigations are made promptly. Another factor in the small number of fires is the low density of population.

There are few hydrants of American manufacture. Usually there is a pit in the sidewalk into which is placed the suction hose of the fire apparatus. Sometimes one finds a small galvanized iron pipe 2 or 2½ in. in diameter extending above the sidewalk. At the top is attached an elbow, a valve, and a short nipple.

The minimum amount of water to be supplied, per capita, has been established at 39 gal. (150 liters). It has been proposed to increase the minimum to 59 gal. (225 liters) to be made up as follows: lavatory use, 1.06 gal.; drinking, 1.06 gal.; cooking, 0.79 gal.; toilet use, 15.85 gal.; cleaning, 5.28 gal.; bathing, 31.70 gal.; unclassified, 4.75 gal.

In estimating future consumption for a period of 30 years, one man's guess is as good as another. With the raising of the standard of living which is in progress in the island, the demands of the past are no guide to future water requirements. Concessions are granted for a term of thirty years to private interests for the construction and operation of water works (called aqueducts). The application for the concession must include the plans and estimates, rules and regulations, and water rates for the term of the concession. At the expiration of the concession the works become the property of the municipality without compensation, unless an extension of time has been granted.

The rates provide for payment for water service either in proportion to the rental value of the building served, the size of the service pipe, nature of the industry or business, or by meterage. The rental value of the building served is the popular method for fixing rates, especially for domestic consumption. At Santiago de Cuba the domestic rate is as follows:

Monthly rent of property.	Annual water rate.
$ 1.00 — $ 2.99	$ 3.00
3.00 — 7.99	4.00
8.00 — 13.99	6.00
14.00 — 24.99	8.00
25.00 — 49.99	15.00
50.00 — 99.99	25.00
100.00 — 149.99	30.00
150.00 — 199.99	35.00
200.00 and more	40.00

These rates are considered low and remain in force because of the limited amount of water that each house receives at the present time. At Camaguey the rates are:

Monthly rent of property.	Annual water rate.
$ 1.00 — $13.99	$ 6.00
14.00 — 24.99	15.00
25.00 — 49.99	20.00
50.00 and more	50.00

In general it can be said that domestic rates vary from 50 cents to 4 dollars per month. A study of one water works showed that 92 per cent. of the consumers are classified as domestic consumers and that they pay 75.6 per cent. of the total revenue.

During periods of prosperity high rents lead to large water revenues, but when the island enters a period of depression a corresponding decrease in water revenue occurs. The rental value of property is determined at the municipal office. Sometimes the amount of water required to be furnished to each property is stated, but no provision is made for determining the actual amount of water consumed. The size of the service pipe is sometimes included in the rules and varies according to the rent of the property. In one concession, houses which rent for $15, or less, per month have a $\frac{1}{4}$-in. connection, from $15–$25 per month a $\frac{3}{8}$-in. connection; from $25 to $40 per month a $\frac{1}{2}$-in. connection; for $40, or more, per month a $\frac{3}{4}$-in. connection is specified.

An example of rates based upon the size of the service pipe follows:

Diameter of service pipe. Inches.	Monthly rate.
$\frac{1}{2}$	$1.00
$\frac{5}{8}$	1.85
$\frac{3}{4}$	3.60
1	5.00

For commercial buildings and industries it is customary to apply a fixed charge based upon the classification. Each type of undertaking is listed, with a rate for each one. The Santiago de Cuba rate schedule lists 73 different shops and industries with rates varying from $3 per year for a saddlery to $2 000 per year for an electric-light plant or railroad.

In some communities the consumer has the choice of two different sized connections. In Cienfuegos a bakery could have a $\frac{3}{4}$-in. connection at $24 per year or a 1-in. connection at $40. A soap factory would pay $48 per year for the smaller connection and $72 for the larger one.

The installation of meters is frowned upon by the people, except for large industries and manufacturing plants. Attempts have been made by the government and by private interests to adopt universal metering but have always met with failure. In one works serving 5 528 consumers there were nine meters; in another having 3 655 consumers there were four. When meters are employed the rates vary from two to ten cents per cubic meter. It is the custom of the country to present bills and collect the amount due at the same time. Little, or no attention is paid to statements sent through the mail. Rarely is payment made at the office; the debtor waits at home for some one to call for the money. Collectors usually receive a percentage of their collections and account every night for the monies received.

Originally the right to discontinue service for non-payment was granted in some of the concessions while in others the owner of the works was required to institute legal action to compel payment. Enforcing payment by this means took many months, and not infrequently accounts were a year old before they could be settled. The National Board of Sanitation recognized the injustice and discrimination of such clauses in concessions and, by general decree, made the procedure of collecting delinquent accounts uniform for all water works. This decree is as follows:

First. All private aqueduct companies are entitled to discontinue water services that are not paid for, without losing the right to employ legal means for collecting the amounts due, in cases where they are authorized to do so.

Second. No water service can be discontinued until at least thirty days from the expiration of the time given for voluntary payments without surcharge, and until the following requisites have been fulfilled:

Third. The aqueduct company shall give notice to the tenant or occupant and also to the owner, fifteen days in advance, at least, of the date on which the water is to be shut off.

Fourth. On receiving the notice of discontinuance of service, when the tenant, occupant or proprietor arrives at an agreement with the aqueduct company to pay the debt in several installments, if he fails to pay such installments on the dates agreed upon, the aqueduct company shall be at liberty to cut off the service, duly notifying the proprietor and the tenant or occupant, so that any of them, if they wish, may pay the debt.

Fifth. In houses or farms occupied by more than one person, the aqueduct company shall be bound to notify the principal occupants. In the case of lodging houses or apartment houses and all buildings in which people live apart, the party in charge of the building shall be notified, and in addition a notice shall be posted at the entrance where it can be seen, advising of the steps to be taken and the date. In such cases advice shall be given beforehand to the Local Sanitary Department of whatever action is to be taken.

Sixth. The notification of the tenant or occupant as well as the proprietor shall be handed by the aqueduct company to the house or farm where service is to be cut off, and the Company shall endeavor to obtain a signed receipt from the person who receives

such notification. Should the house or farm be unoccupied or should no one be found there to receive the notification, or if for any other reason the aqueduct company should not obtain receipt for the notification, or should the persons found at the front of the house refuse to accept same, the Company shall so notify the Local Sanitary Department, for their information, and this shall mean that notification has been made.

Seventh. In all cases the aqueduct company shall send to the local Sanitary Department at least fifteen days in advance of the date of cutting off the water, a list of the services to be discontinued, and shall likewise send a list of the services discontinued to the local chief of the Sanitary Department.

Eighth. The aqueduct company is bound to accept from the proprietor, tenant or occupant, or from any neighbor or third party, payment for the receipts pending for water service given to any farm or house, this being for the proper protection and guarantee of the tenants and occupants, as it is the property which is responsible for payment.

Ninth. The local chief of the Sanitary Department, on learning that the aqueduct company is proceeding to shut off the water from any farm or house, shall take the necessary precautions to see that the property is not left without the necessary water at any time, and shall warn the proprietor that before the service is discontinued he should get the aqueduct company to withdraw the shut-off order, or that he should propose to the local Sanitary Department some other system for supplying the property with water, which would be acceptable to the Sanitary Department. Should the proprietor not be able to settle the matter in any one of the two ways stated, the local chief of the Sanitary Department shall order the closing of the farm or house and shall declare it uninhabitable.

Tenth. In connection with the ruling contained in the foregoing paragraph, the local chief of the Sanitary Department shall take into consideration whether the aqueduct company has obtained the declaration of compulsory service, in which case the local chief of the Sanitary Department can only consent that the house or property be supplied with aqueduct water, but the local chief of Sanitation shall be bound to report the matter to the Director of Sanitation so that he may advise the National Board of Sanitation and Welfare, who shall withdraw the declaration of compulsory service, thus permitting the proprietors, tenants or occupants in the locality to obtain water from any other source that may be approved by the Sanitary authorities.

Eleventh. When the proprietor, tenant or occupant advises the local chief of Sanitation that the aqueduct company has refused to receive payment for the receipts pending for water supplied, in accordance with regulations and rates approved by the National Board of Sanitation and Welfare, provided that such pending receipts do not exceed the amount corresponding to six months of elapsed quotas, the local Sanitary Department shall require the aqueduct to receive said amount, and if the latter should confirm its refusal to accept payment, the Sanitary Department cannot order the closing of the property, and shall impose a fine on the aqueduct, and order it to continue giving service, without losing the right to take legal steps to obtain payment. If the aqueduct is seeking payment for receipts covering a period exceeding six months, and is offered an amount corresponding to the last six monthly payments, or its equivalent, the local Sanitary Department cannot close the property, and it is up to the aqueduct to adopt such means as are recognized by law in order to obtain payment. Should the amount of the quota in question be contested by the aqueduct, the local Sanitary Department shall rule that, for the purposes of its decision, it should be assumed that the amount offered in payment is legitimate, provided that it is not less than that collected by the aqueduct in the last five years previous to the period for which payment is due, as per the receipts, accounting entries of the aqueduct and other elements of proof that may be presented.

Twelfth. In case of litigation due to increase in the price of water service, if the interested party has paid the previous quota, the order for closing the property shall be suspended until a decision is obtained from the competent authorities.

A study was made of 37 aqueducts, excluding Havana and Santiago de Cuba, by Sr. J. A. Cosculluela of the National University and reported in the Cuban *Engineering Review*. Of those studied 25 are privately owned; 4 are owned by municipalities and 8 by the Central Government. Fifteen obtain the water from wells, 11 from rivers, and 10 from springs. The consumption varies from 10.9 to 155 gal. per capita daily, supplying between 60 and 70 per cent. of the population in each community served. The number of consumers per service varies from 4.1 to 16.8. The pressure varies from 6 to 70 lb. per sq. in. There are seven water works in towns having a population up to 5 000, eight in towns with 5 000 to 10 000 population, eleven in towns with 10 000 to 25 000 population, and seven in towns of over 25 000 population.

Cosculluela reaches the following conclusions in regard to Cuban water supplies.

1. Wastage in the distribution system accounts for between 10 and 20 per cent. of the cost of supplying water.
2. The average industrial consumption constitutes from 10 to 20 per cent. of the total consumption.
3. Domestic consumption averages 75 cubic meters per capita annually at a cost which varies from 4.4 cents to 3.3 cents per cubic meter "en servicio a cano libre."
4. The income from domestic service represents a value of $2.81 per capita annually, while that from industrial service is only $0.683 per capita.
5. The cost,* per capita, for providing water in towns of less than 20 000 is $32.45, which is considered excessive. For a population greater than 20 000 this figure is much higher and cannot be determined.
6. In towns of less than 20 000 inhabitants the original investment represents a value of $9.55 per capita. This amount is considered very high, since the sources of supply are near the cities and there are no systems of purifaction in the towns served.
7. Very few aqueducts in Cuba take into consideration the cost of depreciation, but in cases where they do it is always above 6 per cent.
8. Aqueducts in towns of 5 000 people have suffered disastrous effects, both from technical and sanitary standpoints, because very few of them provide regular service or purified water.
9. None of the aqueducts provides for increase in population. They are generally calculated on the basis of 100 gal. per capita daily, which in time is diminished. In this connection, of the 37 aqueducts studied only five maintain a consumption of 100 gal., or more, per capita daily.
10. All of the Cuban aqueducts furnish public service gratis, as this is a fundamental part of the contract. Public service covers the supply of water for fire, street cleaning and also municipal and sanitary structures.
11. The sanitary control of the supply of water in communities, excluding those which belong to the government, comes under the supervision of the Director of Sanitation through the offices of the local chief. The proper functioning of the aqueducts in small communities centers around the Chief of Sanitation.

*Money capitalized.

ACCOUNTING FOR WATER DISTRICTS.

BY JAMES W. GRAHAM.*

[*Read March 9, 1932.*]

One of the most important departments of a water-works system is that devoted to financing and accounting. By it alone do we determine whether the utility will be run upon a sound basis or become known as a losing proposition. Accounting may be defined generally as a procedure relating to the assembly and recording of facts in business transactions in an orderly chronological manner, so that periodical statements may be rendered showing the financial position of any business enterprise and the results from operation.

Water districts in the state of Maine are strictly public municipal corporations uniting two or more cities or towns into a new municipality for the sole purpose of supplying water, leaving all other forms of municipal government to pursue their accustomed functions precisely as though the district had not been organized.

Formerly most of the supplies in Maine were owned by private companies. In some instances the supply was pure and service adequate. In other cases this was far from true. Yet the plants could not be purchased or new ones constructed due to a constitutional provision whereby no municipality can issue bonds or incur debts in excess of five per cent. of its valuation.

In 1899, Harvey Eaton of Waterville, Maine, conceived the idea that this constitutional debt limit no more applied to a new municipal corporation made up of several cities or towns than did the debt of the county or state. Based upon this principle, water districts were created. A water district must, therefore, purchase or build its own works, issue and sell its own bonds, operate the plant and secure sufficient income to cover interest charges, depreciation, operating and maintenance charges. The water districts in Maine have gained public confidence so that their bonds have been considered good investments. Often the price obtained for them has been better than for regular municipal securities.

The management of a water utility has committed to it the task of performing a service which perhaps has a more intimate connection with the welfare of the community than any other form of public utility service. The responsibility of any public utility is to provide the best service that can be rendered by a given plant with a given income. It is here that the value of correct records is appreciated. The purposes of good accounting are to give information of the operation and to reflect true financial condition.

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The Public Utilities Commission of Maine has prepared a system of uniform classification of accounts under which all water utilities of the state must operate. The commission recognizes the importance of bookkeeping, for in the initial paragraph of its general instructions we read: "All accounts kept by any corporation or person within the scope of the present order shall be kept by the double entry method." Succeeding paragraphs declare that all accounts shall be arranged in two groups, namely, balance-sheet accounts and operating accounts, and the distinguishing features of each group are clearly set forth.

With respect to property we are instructed that any property having a life beyond one year is a balance-sheet account, otherwise it is an operating account.

Fixed Capital Account. This account should contain the cost of all existing units of property, the various items to be supported by journal entries and vouchers giving correct dates of installation, location, capacity and detailed description of units in such a manner as to leave no room for questioning.

A public water supply is unlike many other business enterprises inasmuch as the capital accounts are changing daily. Each time a new service is installed, a new main extended, or a new meter set, we add to capital investment.

When a utility is enlarging and improving its service there often occur retirements of property and, as the fixed capital or investment account must contain only property that is in existence, all retirements should be deducted at the figure originally recorded and charged against the depreciation-reserve account. It is therefore of the utmost importance that the accounts should be carefully kept.

The method employed by the Portland Water District is to have each extension job, each new service installed or renewed, each new meter set or any other addition to the plant, reported daily from report cards turned in by foremen and service plumbers. These cards show the number of hours per day for each man on the job together with all materials and machinery used. When the job has been completed the daily report card items are brought together on a permanent record extension, or service, card and these amounts entered in the journal charged to fixed capital.

Depreciation Reserve Account. The uniform classification has provided for a depreciation reserve, against which retirements and rehabilitation of property should be charged. Even after a somewhat extended use of the classification, there appears to be more or less confusion in some quarters regarding the purpose and operation of the depreciation reserve.

Depreciation is commonly divided into two sections: one known as maintenance or operating expense and the other as depreciation. That part called operating expense, or maintenance, is covered by current repairs in replacing and repairing small parts to prolong the length of service of the various units of property.

The depreciation reserve is set up by charging annually to operating expense an estimated sum based on the operating experience of the district. Against this reserve may be charged losses of property from wear and tear not covered by current repairs and losses from obsolescence, inadequacy or extraordinary casualty. The charge to operating expense is a current transaction to meet future retirements that are bound to come. Instead of "swamping" by charging to operation expense in any one year the full amount of retirements, the cost is spread over a period of years and paid for by those who use the property, not a future group of customers. Those who waste the property should contribute toward its replacement. The charge setting up the reserve is as much a part of the regular operating expense as current repairs, the only difference being that the actual performance of replacement is a future instead of an immediate transaction.

To the reserve section should be charged the cost of all retired property less salvage. To quote from the Classification: "When any property is retired from service, the original money cost thereof — estimated if not known — less salvage, should be charged to the reserve account 'Reserve for Depreciation.'"

Equalization and Apportionment. The purpose of this account is to provide a medium through which the cost of operating garage, storehouse, insurance and many other items may be spread uniformly over the year and applied to construction or to operations as the transactions may indicate. No difficulty is found in charging to each job the common labor and materials used, but there are many items of cost that cannot be definitely charged each day. There are the so-called "overhead" items, general supervision, bookkeeping, liability and industrial accident insurance, loss and waste of materials, cost of storing and handling materials, interest on cost during construction, legal expenses, settling damages and other contingencies that are always present and that should be intelligently allocated by some method to their proper places in capital accounts or operating expenses. If no part of this general overhead expense is charged to capital accounts where extensive construction work is being done, the operating expenses are increased and the capital account does not truly reflect the actual cost of the work.

In the Portland Water District we have what we call an "equalization account." From experience we find that to correctly record the total cost of any extension there must be added to actual disbursements for labor approximately 20 per cent. for their overhead accounts, and to actual cost of material about 10 per cent. For instance, if the daily report cards on a given extension show actual wages paid of $100, there are added $20 more for overhead. This covers the cost of items such as insurance of all kinds, lost time traveling to and from the work, sickness, and vacations, as experience shows that it is impossible to have any employee 100 per cent. employed at all times. This account is also intended to carry something of supervision and planning of the work by the superintendent, general

manager, engineer, attorney, timekeeping and other overheads that cannot be definitely estimated and charged each day to each job. Therefore the percentage method is adopted. The percentage for materials covers the cost of carrying the materials from date of purchase until used, including storage, interest on cost, breakage and wastage. These percentages are added to the costs and then allocated or credited to the appropriate overhead ledger accounts pro rata, *i.e.*, if our overhead accounts for the period aggregate $10 000 and the equalization percentage amounts to $2 000, then 20 per cent. is credited to each ledger account.

This method covers extension work done by our own crews. What shall be done in the case of contract work? Let us examine a contract recently completed by the District by the furnishing and laying of 48-in. concrete pipe. The contract price for the work was $200 400 which has been, or will be, paid the contractor. Shall we add this sum to our capital account and stop there?

Analysis of our payments on account of the work as it progressed shows that if we reckon interest at the rate of 6 per cent. on these payments up to the time the work was completed and ready for use, the interest alone amounts to $3 960. Is it not fairer to charge this item to the cost of the pipe line than to carry it as an operating expense for the year? Also, many hours of the general manager's time, of the engineer, attorney and general office clerks were devoted to the proper planning, superintending, financing and accounting required for the efficient completing of the work. So in this case the District adopted a flat 4 per cent. of the contract price as an equalization or overhead item which added $8 000 to the contract price, the overhead ledger accounts were credited with the same amount, and the operating expenses of the District showed a corresponding decrease. In this item alone, $8 000 was correctly added to fixed capital which otherwise would have been carried as an operating expense.

The charter of the Portland Water District provides that rates shall be established so as to provide revenue for the following purposes:

(1) To pay the current expenses for operating and maintaining the water system.

(2) To provide for the payment of interest on indebtedness created or assumed by the District.

(3) To provide each year a sum equal to not less than one nor more than five per cent. of the entire indebtedness created or assumed by the District, which sum shall be turned into a sinking fund and there kept to provide for the extinguishment of such indebtedness.

Under this third provision all improvements and extensions to the plant must be capitalized and paid for by bond issues. The water rates are therefore fixed just high enough to pay the operating cost of the District. In other words, water is furnished consumers at as near cost as can be estimated.

I have confined my remarks in this paper mostly to capital accounts.

However, there are other accounts of equal importance, any one of which would be a discussion in itself.

The saving of time and money in account keeping is of deep interest, but far greater is the value of a set of accounting records so complete that any essential fact can be found quickly or that any needed comparison of one period with another, or one utility with another, can be made without delay and in the full confidence that nothing has been omitted from the accounts of either period or utility. Then only can conclusions be drawn based on all the facts.

Those who grope in the dark without having some sort of plan to follow never progress very far in their undertakings.

UNACCOUNTED-FOR WATER IN NORWOOD, MASS.

BY C. A. BINGHAM.*

[*Read January 18, 1932.*]

When the writer returned to Norwood in 1928 he was confronted by a report on a municipal and industrial survey completed by a nationally recognized bureau through the aid of the Chamber of Commerce and one of the local luncheon service-clubs. This report, among other statements, said that approximately 33 per cent. of the water pumped into the system was not accounted for; it likewise gave a strong picture of lack of system in several branches of the water department. A few months later Norwood was able to secure again the services of its former Superintendent of Public Works, and an immediate reorganization of the department was put into effect.

Last year, in order to determine the results accomplished, a careful check-up was made of the various uses of water and the amounts in which water was distributed. This check-up included a Pitometer survey. It was a pleasure to find that up to 81.8 per cent. of the water supplied to Norwood could be accounted for. We often hear superintendents claim that they can account for 90 or 95 per cent. of the water pumped from their stations. This will always produce a smile; more especially so when,— as happened to the writer — a superintendent confided that he was accounting for 95 per cent. of his supply and, upon being questioned, admitted that his system was only about 70 per cent. metered and that he had estimated the use from unmetered services. In one city, it is said, fire service income is converted into gallons and added to meterage.

The 18 per cent. of water unaccounted for on the 42 miles of mains in Norwood represents about 5 000 gal. per mile per day. This is above the figure of 3 000 gal. usually given as allowable line-loss. Yet we admit that we cannot account for this excess. There may be leaks which the Pitometer survey cannot locate; or there may be under-registration of meters which by accident have not been checked. It is our hope to continue the investigations until we discover just where the discrepancy lies. Our meter readers have been instructed to be even more observant for leaks than before. An inspector will make a house to house survey, and we shall continue to bring in for a shop check-up all meters in service over seven years.

Total Pumpage. During the year 1930, the Venturi meters at the two pumping stations recorded 418 015 000 gal. of pumpage. The calendar year does not cover exactly the dates of the quarterly readings and billings of domestic meters, but since the pumpage for 1930 was within 8 000 gal.

*Town Manager.

of the average yearly value for eight consecutive years and since the observations for the months preceding and following this period were almost identical, we can safely neglect this discrepancy. A Pitometer test showed one Venturi meter exactly correct, while the Venturi meter at the second station was found to over-register 9 600 gal. in a daily pumpage of 1.5 m.g.d. This difference is only 0.6 per cent. which is an excellent showing. Even this small difference was taken into account. For the year it would reduce the net pumpage at both stations to 414 511 000 gal. to be accounted for.

Factory Meters. Forty-one per cent. of our metered water passed through thirty-eight active industrial meters. These are read and billed every month. The total number of cubic feet registered for the year was 14 109 300. As these meters bring in much money they are submitted to frequent inspection, at least as far as "stopped registration" is concerned. The Pitometer survey reported the thirteen large meters in the largest industry showing an accumulated under-registration of 39 089 g.p.d. This, together with the average under-registration on all other factory meters, — one 4-in. meter being 10 per cent. short — would make the true delivery to all factory services 108 434 423 gal.

House Meters. The system is 100 per cent. metered, the number of domestic and business meters being 2 647. There are twelve districts, grouped into three sections so that an equal amount of reading and billing is done every month in several of the twelve districts. This gives the owners quarterly bills instead of, as formerly, semi-annual bills, thus saving owners considerable excess if they heed the notices left by the meter readers. The reading of 632 meters in one district and 932 and 1 083 meters in the other two districts means the covering of equal territories and takes two readers twelve days. The factory meters require one day, and during the balance of the month the readers cover the 4 500 electric meters. One supervisor and three clerks do all the billing by machine for both utilities. Open-faced envelopes are used, and a postage meter has replaced stamps. As office system is not one of the topics of this paper, the system of collection and shut-offs will not be described except to note that out of $82 000 a year in water bills an average of not over $900 is in arrears at any time. When payments are sixty days overdue, services are shut off. In the electric department annual bills of $240 000 find not over $500 delinquent at any time. These services likewise are shut off and the deposits are applied against the bills.

Domestic Consumption. The annual total of readings for this class of service was 20 236 900 cu. ft. The average under-registration for a large number of household meters was 2½ per cent. This brings the total number of gallons delivered through domestic services to 155, 571, 165. "Stopped meters" are billed on previous average use, and these amounts are noted in the table of use and percentages.

CLASSIFICATION OF USE OF WATER.

	Gallons.	Percentage.
Construction use	2 698 000	0.65
Flushing & Puddling	3 973 200	0.96
Stopped Meters	2 260 000	0.51
Smaller Leaks	16 444 400	3.97
Fire Use	750 765	0.17
Main Leaks	48 910 000	11.81
Domestic Use	155 571 165	37.55
Manufacturing Use	108 434 423	26.18
	339 041 953	81.80
Unaccounted for	75 469 047	18.20
Total Pumpage	414 511 000	100.00

Unmetered Use. Practically all hydrant use (except in the case of fires) is required to be metered and during the construction season all water used for road rollers, sidewalk construction, etc. is metered. A strict account is kept even of hydrant flushing and trench puddling. As far as possible every small leak is checked as to flow and approximate duration. The last Pitometer survey found a complete break on a 6-in. main. Measurements showed that 134 000 g.p.d. were escaping. This figure was checked by the fact that immediately after a new pipe was inserted pumpage dropped 129 000 g.p.d. All the water reached a sewer or seeped through a gravel stratum to a nearby pond. This one leak accounted for 48 910 000 gal. The Fire Department records showed 750 765 gal. of water used during the year in the extinguishing of fires.

THE NASHUA FIRE OF MAY 4, 1930.

BY HON. WILLIAM F. SULLIVAN.*

[*Read May 11, 1932.*]

On January 1, 1930, speaking of the Fire Department, the Mayor of Nashua in his message said: "Conflagration hazards are ever present, and there must be no letting down in the maintenance of the necessary equipment or in preserving the morale of the membership of the Department."

On Sunday, May 4, four months later, it was Nashua's turn to undergo its harshest experience by fire. On that eventful day the skies were sunny and there was a summer temperature of 70° F. The good people of Nashua, like folk in other parts of New England had returned from church services, and everywhere reigned peace and contentment. Nothing unusual had occurred to distract the attention of the inhabitants of the city. There was no thought in the mind of anyone that it was Nashua's turn to be visited by the red demon of destruction, who has always been and is now lurking just around the corner in every community in the land, to strike viciously at its life and property.

The Conflagration.

Little thought had been given to the basic cause of such a catastrophe which in this instance, was, a long wooden railroad bridge, or rather two parallel bridges, nestling in a ravine. These structures were sunbaked, oil-soaked and boarded or sheathed to protect the trusses against the ravages of time. It was inevitable that once a fire was well started, the whole structure would become a fiery mass. The protective covering was the principal reason why fire streams could not strike the heart of the fire and quickly extinguish a blaze which ordinarily would call for little or no comment.

For days prior to May 4, the weather had been dry to the point of drought, the temperature at times rising over 80° F. and flirting with the nineties. The aridness was unusual and the humidity the lowest ever recorded in the region. The wind contributed chiefly to the spread of the fire. The New Hampshire Forestry Department observer on Jeremy Hill, about six miles away, noted at the beginning of the fire that the wind was blowing with a velocity of 45 miles per hour, and that within thirty minutes there was a 54-mile-per-hour gale blowing.

Wood-shingled roofs predominated on the structures and dwellings in the path of the wind and the flames. In addition the territory was the center of industries whose chief products were of wood. Lumber yards and stave yards contained vast quantities of highly inflammable materials. The volumes of lumber and wood products were estimated at seventy million

*Mayor of Nashua, N. H., and President of Pennichuck Water Works.

board feet, and much of the wood was on the "sticks" for air drying later to be used for cooperage, boxes, finish and other articles. The rapidity with which the fire spread and was scattered by the wind was truly terrifying. The fire was aërial, horizontal and at times invisible. Buildings burst into flames some distance in advance of the actual fire and for no visible reason. Intense heat and gases prevailed everywhere, sparking, igniting structures that offered, at best, only feeble resistance. It was clearly evident after the first thirty minutes that the fire was beyond the power of any fire department to confine or extinguish. Property in the path of the flames and wind was doomed.

The Nashua Fire Department responded to a box near the windward end of the bridge. The bridge ran southeasterly in the same direction in which the wind was blowing. The seat of the fire, near the middle of the bridge could not be reached because of the protective sidings and top. There had been provided and kept on the bridge a barrel of water and a pail. If detected in time a dash of water would undoubtedly have extinguished the flames. The firemen, attempting with hose streams to strike at the seat of the fire, were opposed by the gale which bent back the streams and broke them into spray turning the water upon the nozzlemen. The fire raced toward the men with such fierceness that at the very beginning of the conflagration two lines of hose were abandoned and burned on the bridge.

Right in the path of the fire and close to the bridge was a large dwelling with a slate roof. This was saved. In the rear of this house and nearer the bridge was a light two-story, two-car garage. The fire engulfed this building and it is believed that its light materials of construction, together with the bridge sidings, furnished the lighted torches which first sprayed onto the highly inflammable roofs and into the lumber yards. The fire department repeatedly extinguished roof fires in the vicinity of the bridge, but the necessary shifting had to be done so suddenly that while the moving from hydrant to hydrant was carried out efficiently, it could not humanly be done quickly enough, and it was beyond the mobile power of any one department to meet the many calls. The Chief of the Nashua Fire Department counted twenty-six separate roof fires ten minutes after the fire started. Twenty minutes after the fire began the Sunday-afternoon golfers were driven from the links of the Country Club by a cloud of firebrands. The Agent of the Nashua Mills sent part of his private fire brigade to spray the club buildings, an act which undoubtedly saved them.

Four hundred feet from the fire and in its path was a nest of combustible buildings made up of large frame sheds and storage buildings with tinder roofs. These sheds were partly open and filled with dry lumber and accumulated materials owned by a long established construction company. This whole section was soon a roaring mass of flames. Fire would quickly attack a structure; then this fire would lash at the buildings to the windward. Occasionally the fire would jump a structure and strike with fury beyond.

The carrying power of the gale was amazing, spreading live embers like fireballs into the great piles of dried lumber and staves. Fragments from the fire were carried down the Merrimack Valley, and burned leaflets from the Baptist Church prayer books were picked up in the streets of Woburn, Mass., before five o'clock of the same afternoon. In Chelmsford and beyond, live brands as large as a half shingle were falling and igniting brushland.

Alarm after alarm, call upon call, no ordinary city could afford to carry or muster a department to meet such an emergency. A man hurried up and excitedly cried out: "Proctor Brothers lumber yard is afire." (This occurred long before aid from other communities had arrived.) There

FIG. 1.—BURNING BUILDINGS ON NEWBURY STREET, NASHUA, N. H.

were neither men, apparatus nor hose to answer the call. In a few minutes this yard was a fiery mass. The great waving sheets of flame stormed against frame and brick factories and lapped up lumber yards. In places they gave the appearance of Niagaras of flames, drowning, as it were, and destroying with red and white heat homes and the adjoining industries. Sprinkler systems in the factories were useless, for the flames smashed water resistance from without. So for hours the demonstration of red fury continued warlike and completed its work of destruction until the fire-invaded territory lay wasted. Even the ashes disappeared in a cloud of dust and the ground was whipped clean. On the fringes and beyond, however, there were aid, succor, sympathy, and friendliness on all sides.

Thirty minutes after the first alarm the fire was out of control, and for seven hours terror and desolation, but without demoralization, followed in its wake. In that short time 350 families were made homeless, and 250

dwellings with 50 garages and other buildings were destroyed. The industrial losses were great with a total of nearly three million dollars.

To reminisce, Nashua experienced just another Sunday fire, for it seems fated that Sundays and holidays are propitious days for big fires. Mrs. O'Leary's cow kicked over the lantern that started the burning of Chicago, Ill., on a Sunday in 1871. Paterson, N. J., was ravaged by flames on a Sunday in 1902; Baltimore, Md., had an appalling fire one Sunday morning in February 1904; Chelsea, Mass., was partially destroyed on Sunday,

TABLE 1.— OUTSIDE AID IN NASHUA FIRE.

Town.	Approximate Time of Arrival.	Number of Motor Pumpers.	Number of Men.	Number of streams used.	Distance travelled in miles.	Approximate Time	
						Run. Min.	Operation Hrs.
Hudson, N. H.	2.35	2	10	3	1	5	9
Merrimack, N. H.	2.55	1	20	2	8	15	16
Westford, Mass.	3.15	1	8	1	12	24	14
Milford, N.H.	3.20	2	30	5	11	20	9
Lowell, Mass.	3.25	4	50	4	14	22	8
Manchester, N. H.	3.30	2	20	5	18	35	16
Dracut, Mass.	3.50	1	8	Reserve	12	20	..
Chelmsford, Mass.	4.20	2	35	2	13	18	9
Pelham, N. H.	4.20	1	9	Reserve	10	20	..
Lawrence, Mass.	4.50	1	10	2	26	40	5½
Pepperell, Mass.	6.00	1	14	2	10	45	9
Hollis, N. H.	7.00	1	15	1	8	20	10
Dunstable, Mass.	7.00	1	12	2	10	35	6½
Woburn, Mass.	7.10	1	11	Reserve	32	47	..
Raymond, N. H.	7.10	1	8	1	28	40	8
Winchester, Mass.	7.15	1	10	Reserve	32	60	..
Belmont, Mass.	8.10	1	6	2	32	60	11
Arlington, Mass.	8.20	1	10	2	30	55	8
Lexington, Mass.	9.45	1	10	1	28	45	8½

A few towns sent men but no pumpers.

TABLE 2.— EQUIPMENT AND MEN, NASHUA FIRE DEPARTMENT.

No.	Equipment.
4	1 000-gal. pumps.
5	combination cars with booster pumps and tanks.
1	aërial truck.
3	city service trucks.

No.	Men.
43	full-paid.
17	on call.
60	Total.

April 12, 1908; and many other disastrous fires have occurred on Sundays. The reasons in most cases are obvious. Sunday is a day of rest when a community relaxes its activity and supervision slackens. It has been thought that if this fire had occurred on a week day, it would undoubtedly have been detected sooner and that a railroad man or someone else would have used to good effect the ever-ready barrel of water kept on the bridge.

At 2.35 P.M. the neighboring towns of Hudson and Hollis answered the call for help; later came help from other adjoining towns. Aid from Lowell arrived at 3.20, and from Manchester at 3.25 P.M. Then the Sunday afternoon radio announced the destruction going on in our city. Firemen from Lawrence, Winchester, Lexington, Belmont and other places, looking into the sky saw a part of Nashua taking flight. Did they hesitate? No! Even without an appeal they came through the auto-choked highways. They raced from the suburbs of Boston, and in a short time we had over thirty high-powered pumping engines and crews flanking the burning district.

The table on page 207 shows the spirit of neighborliness. Men and apparatus came many miles to help, and one Lowell fireman paid the supreme sacrifice for duty's sake.

This reinforcement of men and equipment relieved our hard-pressed firemen. It was difficult amid the clang and clash of apparatus and the swish of flames to manœuvre this reserve to the most strategic positions where the important ammunition, water, was most abundant, as hydrant ratings had gone by the board and normal pipe capacities out of balance.

Under all conditions, particularly in a large-sized district, hydrant-delivery values are different and ever-changing with heavy demands. All firemen are not familiar with pipe capacities and often expect, with the present-day oversized pumpers, outlying and dead-end districts to furnish an unlimited number of standard fire streams, when a short time ago a galloping three-horse fire engine would make a big showing with two streams. Many a successful job of fire-fighting has been done by a chief who realizes the elevation and pressure at each hydrant, and who from a knowledge of the piping system decides quickly upon the number of streams and size of nozzles to be used. Technical information is often necessary for firemen to appreciate whether a fire is on a dead end or not.

The draught was enormous, for in addition to the abnormal uses for fire extinguishment there was the loss from abandoned hydrants and hose lines. Every building burned left a bleeding service. In addition there were 8-in., 6-in. and 2-in. industrial fire-services wasting large quantities of water. On account of the heat these services could not be shut off until 8 hours after the start of the fire.

The number of broken and bleeding services was 206 with a total cross-sectional area (no allowance being made for reduction of section by corrosion), of 231.59 sq. in. or the equivalent of one 17-in. or two 12-in. mains. This is shown in Table 3.

TABLE 3.— BROKEN SERVICES.

Number.	Diameter. in.	Area. Sq. in.
1	8	50.27
1	6	28.27
1	2	3.14
1	1¼	1.23
173	1	135.87
29	¾	12.81
206		231.59

A survey was made at twenty-one selected locations, and it was found that the combined fire flow exceeded the theoretical requirements by 6½ per cent. with a residual pressure of 20 lb. per sq. in. pressure at the hydrants.

TABLE 4.— FLOW TESTS.

No.	District.	Location.	Fire Flow — g.p.m. Required.	Available for Engine.
1	Principal	Main between Factory & Water Sts.	5 000	8 400
2	Mercantile	Garden & Pearl Sts.	5 000	5 000
3	Manufacturing	Franklin & Locust Sts.	4 000	4 200
4	Manufacturing	Broad St. & Amherst Terrace	3 000	950
5	Manufacturing	Chandler & Canal Sts.	4 000	4 800
6	Manufacturing	Bridge & C Sts.	3 500	3 500
7	Manufacturing	Crown & Chase Sts.	3 500	2 800
8	Manufacturing	Arlington & Burke Sts.	3 000	800
9	Manufacturing	Hollis & Quincy Sts.	3 500	3 600
10	Manufacturing	Marshall & Hollis Sts.	3 000	3 000
11	Manufacturing	Lake & Ash Sts.	3 500	1 900
12	Residential	Lake & Nagle Sts.	2 000	1 100
13	Residential	Ritter & Blossom Sts.	1 500	1 300
14	Residential	Ledge & Eaton Sts.	2 000	1 800
15	Residential	Abbott & Merrimack Sts.	2 000	6 800
16	Residential	Chester & Stark Sts.	1 500	2 400
17	Residential	Summer & Cross Sts.	2 000	1 900
18	Residential	Spring & Temple Sts.	3 500	5 900
19	Residential	Haines & Newbury Sts.	1 500	1 700
20	Residential	Taylor & Fifield Sts.	1 500	1 200
21	Residential	Clement & Main Sts.	1 000	300

Throughout the city, while the conflagration was still raging, residents were spraying buildings with water from hundreds of garden hoses, many of them doing good work by quenching sparks and fire brands.

THE WATER SUPPLY.

Nashua's water supply had to be relied upon solely to meet the test. No nearby cities or towns are linked up with this city's system, and we believe the showing under the circumstances to be creditable.

Back of the sudden and extraordinary demand for water was an unusual reserve supply for a city of this size. Stored in the supply pond were over 50 m. g. of ground water which is kept for daily needs. This reservoir of water is obtained from flowing wells, which yield about 5 m.g.d. In addition, we had 650 m. g. impounded surface water of excellent quality which could be delivered to the pumps under a head of 40 ft.

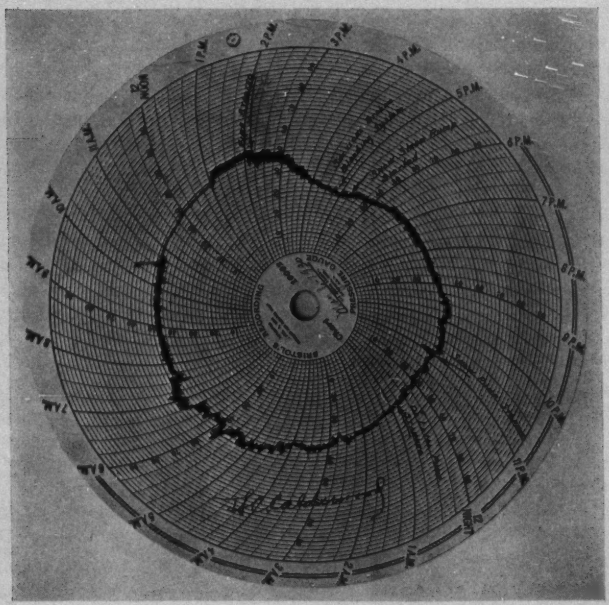

FIG. 2.— PRESSURES AT WATER-WORKS OFFICE, 11 HIGH ST., FROM 10.45 A.M. SUNDAY, MAY 4, TO 10.45 A.M. MONDAY, MAY 5, 1930.

When the fire started at 2 o'clock in the afternoon, the 6-m.g.d. water-power pump was running and the 4 m.g. distributing reservoir, with a depth when full of 13 ft., held 11.6 ft. of water; at three o'clock it had gained 0.3 ft. to 11.9 ft., and the draft was 5 500 g.p.m.; at 4 o'clock it was at 11.7 ft. with a draft of 7 000 g.p.m.; at 5.20 P.M. it was 11.3 ft. with a draft of 7 500 g.p.m., or 10 800 000 g.p.d. At 8 o'clock, with the fire under control, the reservoir held 10.8 ft. of water with a draft of 6 000 g.p.m. At 11 o'clock the Snow Steam pump was stopped and the draft was 5 500 g.p.m. or 7 920 000 g.p.d. During the height of the fire a pressure of 73 lb. per sq. in. was maintained on the pumps.

The water level of the distributing reservoir dropped only 0.9 ft. during the first six hours of the fire. The total pumpage from 2 P.M. Sunday to 9 A.M. Monday was 6 400 000 gal. of which about 5 250 000 gal. went into the fire area during a nineteen-hour period.

At 2.20 P.M. the pumping station was notified to stand by and start an 8-m.g.d. Snow triple-expansion steam pump. The 6- and 8-m.g.d. pumps were operated together from 5.20 until 11 P.M. with a combined capacity of 14 m.g.d. The lowest pressure recorded in the office gage located on High St. in the center of the city was at 4.50 P.M. when it went down to 32 lb. per sq. in. for a short time. The range in pressure during the fire at this point was from 52 to 32 lb. per sq. in. with an average around 41 lb. per sq. in.

The supply pumps and reservoir are located in the extreme northerly part of the city, about 3.4 miles from the middle of the fire area which was in the southeasterly part. The fire area which was about $1\frac{1}{2}$ miles long and $\frac{1}{3}$ mile wide, burned itself out in the extreme southeastern portion of the so-called built-up section of the city where the pipe lines in some cases ended in terminals.

The city's distribution system is elongated running north and south about five miles, and east and west about two miles. Because of rivers, brooks and railroad lines, grid-iron construction is more difficult in Nashua than in other places where topography makes for easier and less costly elimination of dead ends.

Economically, a small city whether it has a municipally- or a privately-owned water works cannot afford to build a distribution system to meet a 100 per cent. conflagration demand in all sections, especially when the fire area is removed from the center of the community and the high-value district.

A distribution system, as originally planned, is often unbalanced by lack of a municipal planning and zoning ordinance. Many times because land is available or low in cost, a small factory or a hazardous business locates in a residential district. This often brings up the question of increased fire protection, primarily for the purpose of a reduced insurance rate. At times the cost, to meet the request, would exceed the value of the property. As the millenium has not been reached and there is not at the present time a fair distribution of costs between the uses of water for fire extinguishment and other purposes, water works must continue to worry along until there is a better understanding of what it costs to produce and deliver water and must base charges equitably upon fire protection and other uses. This brings up the age-old water-works question of how much it is fair to charge the rate payer, and how much the taxpayer.

Large cities by necessity have larger mains and arteries for general uses, and the spread between daily uses and ready-to-serve fire-needs gradually merges as cities increase in size and population.

The main feeders into the city are 24-, 16- and 12-in. cast-iron pipe

lines, with laterals 16, 12, 10, 8, 6 and 4 in. in diameter. Crossing the Nashua river we have four lines, one 24 in., two 20 in., and one 12 in. One half mile west of the conflagration area is a main 24-in. feeder with a 12-in. pipe coming around from the east. In the fire area itself there were 12-, 10-, 8-, 6- and 4-in. pipes fairly well gridironed for an end section far away from the source of supply.

Relief Work.

During and after a conflagration, duties must be performed by a community other than those which can be accomplished by the fire and water departments. If a bright sunshiny Sunday afternoon is selected to stage on a grand scale a spectacle which is advertised by alarms, telephones, radio and a black cloud in the sky, there is little wonder that it attracts a vast audience. In a very short time we had a traffic jam which clogged the highways. The Police Department called every man for duty; in addition many volunteers, including ex-service men, responded as traffic officers so that there might be order instead of chaos on the highways. About five o'clock it was thought advisable to call on the militia to inspire confidence and protect unroofed property. This precaution was worthwhile, and the guardsmen aided in handling the throng of sightseers. The Boy Scouts, too, offered their services and did their bit.

While the fire was raging, a special meeting of the Mayor and Board of Aldermen was held and the Mayor was authorized to spend $50 000, if necessary, for temporary relief. While the city was burning, the relief organizations met and gave a demonstration of real community spirit. A great wave of sympathy and good will flowed over the stricken area. By the light of the fire the people of the city came in marvelous fashion to the relief of the homeless. Relief committees pushed forward in the wake of the flames, feeding, clothing and sheltering large numbers of the homeless, taking them into their families as guests.

Then came the question of permanent rehabilitation of workingmen and their families and of middle-class people who had suffered most. The people of New England, Nashua and the Red Cross gave over $300 000 in money and $75 000 in supplies to assist in placing many people back on the same standard of living which was theirs before May 4.

An able and efficient committee on awards was chosen which as trustee of the funds did a difficult piece of work on an equitable and just basis. Then the municipality found itself faced with the problem of taking this area and with sound judgment replanning it and improving upon what had been there before. The opportunity must be seized to widen streets, secure park areas and enact restrictive legislation.

Two years after, we find as the fruits of careful rehabilitation many new houses with modern improvements and factories rebuilt on the burned area or elsewhere. Today, the so-called Crown Hill section is destined to be a better place to live in. Our experience has shown that good sometimes

comes out of suffering; just as past experience has demonstrated that in the rebuilt portions of all cities which have been destroyed by fire the new construction has developed a better and more desirable place.

The question is often asked what started the fire at a moment when the combination of wind, drought and wood-shingled roofs was just right to produce a conflagration. It remains a mystery whether it was an impish match, a non-stop cigarette, a thoughtless boy or an evil-spirited person who sparked the inflammable structure which wrought so much havoc. It is of little moment now to know, but it must remain a challenge to prevent if possible a repetition of such a calamity. Risks can be eliminated by regulations, building codes, zoning, planning and inspections, all of which will go far to remove present-day hazards and prevent useless waste by fire in the future.

EFFECT OF PRESENT ECONOMIC CONDITIONS IN MASSACHUSETTS UPON WATER SUPPLIES.

BY ARTHUR D. WESTON.*

[*Read November 18, 1931.*]

Many water-works and public-health authorities have looked with concern upon the general practice during the past year of appropriating huge sums of money for the relief of unemployment. They have feared that such appropriations might result in a curtailment of necessary water-works construction or less efficient water-works management. This concern appears well founded when one considers that probably no other medium in every-day life has such an important bearing upon the public health as the public water supply.

In September of this year this feeling had become so general throughout the country that it resulted first in resolutions being offered by the Conference of State Sanitary Engineers which were almost immediately followed by similar action on the part of the American Public Health Association and later by the New England Water Works Association.

The resolutions of the Conference of State Sanitary Engineers read in part as follows:

One of the major factors incident to the present economic crisis is the general inability to provide employment and find markets. It is essential that when industry is unable to employ workers, then official and voluntary relief agencies using public and private funds should provide work that will relieve such unemployment as far as practicable. The necessity for providing an outlet for productive labor on projects of public benefit is a problem that warrants careful consideration.

Your committee believes that a reasonable share of such work could advantageously be done for the improvement of environment and the health of our people. Such constructive projects might include the improvement of water supplies and distributing systems, works for the collection and disposal of sewage, refuse, garbage and other municipal wastes, malaria and mosquito control, rural sanitation and reclamation of waste or wet lands for recreation and other useful purposes.

State Health Departments should, during this emergency, insistently press for the accomplishment of construction or work really needed for the protection of the public health as such not only creates employment but takes advantage of the present low cost of construction and provides installations and results of permanent value useful to the community rather than mere temporary expediency. Furthermore, the great value in engaging the unemployed in useful work cannot be over-emphasized.

With these facts in mind your committee finally recommends that the necessary steps be taken to make surveys in each State of needed sanitary work in order to consummate such public health projects as will give useful work to the unemployed.

*Chief Engineer, Massachusetts Department of Public Health, Boston, Mass.

The Conference of State Sanitary Engineers appointed a committee to keep in touch with all phases of the matter, this committee being known as the Committee on Unemployment Relief. Under the able guidance of its chairman, W. L. Stevenson, Chief Engineer of the Department of Public Health of Pennsylvania, it has caused surveys to be made throughout the country of the conditions referred to.

The survey made in the state of Massachusetts, which consisted of a canvass of fourteen representative cities, showed practically no curtailment of water-works activity. These municipalities represent a total population of 528 025 as of 1930 or 12 per cent. of the total population of the state and a valuation of $753 826 717 or 10 per cent. of the total assessed real-estate value of the state. The result of the canvass showed that 14 per cent. predicted increase of water-works construction in 1932 and 65 per cent. the usual amount of such work. Three cities predicted a slight reduction in their water-works program, and only one anticipated a serious reduction. Regarding plans for personnel, one city predicted an increase, 79 per cent. predicted retention of the present forces, one a slight decrease, and one a serious decrease, this one being the same which anticipated reduced appropriations because of local municipal finances. When interviewed regarding bond issues, it was learned that in all cases in which issues were requested, authorization had been granted. In one municipality an $800 000 project of enlargement of the water-works system was commenced, another has under consideration a program involving an expenditure of $350 000, while a number have commenced special water-works projects involving expenditures of $20 000 or more.

It is believed that the canvass of Massachusetts is fairly representative of the water-works conditions in that state, and that it can reasonably be expected that the appropriations for water-works construction and for management and maintenance of water-works plants in Massachusetts will not be materially curtailed during the year 1932. A more extensive canvass to include the other New England states probably would show conditions similar to those found in Massachusetts. Such conditions speak well for water-works officials and indicate that they have the confidence and backing of the community.

It is interesting to note from a recent report concerning appropriations made in Germany for the relief of the unemployed that while loans or subsidies are made by the Reich or state government for emergency work in addition to those which normally would have been made under the municipal budgets, the laying out of playgrounds and public parks was not considered "economic or productive work." On the other hand, improvements of river ports and inland navigation, the construction of canals, roads and bridges, water works and reservoirs, electric power plants and transmission lines, working-class dwellings, drainage and sewage-disposal systems were considered economic or productive work and worthy of loans to the municipality or grants from the Reich or state government. In granting the

loan or subsidy, the government reserved the right to insist that some of the local unemployed be provided with work in connection with the project. An example of the character of the joint subsidy operation is shown in the construction of a large dam and reservoir known as the Zillerbach Reservoir in the Harz Mountains in the province of Saxony. This reservoir has a capacity of about 870 million gallons and according to estimates would take about 66 000 working days to be completed. In carrying out this work it was estimated that the labor exchange would contribute 1 020 000 marks in subsidies for the employment of men shown on its register. The loan made by the Reich through the labor exchange was granted for a period of 25 years at an interest rate of 5 per cent.

With a view to relieving the serious unemployment situation in Saxony, work was commenced on a certain project for supplying the inhabitants along the Elbe River in central Saxony with water for drinking and other domestic purposes, the construction in this case being delegated to a public corporation organized for the purpose. It was estimated that this work would extend over a period of two years and would cost about 20 000 000 marks.

Much the same difficulty has been experienced in Germany as in this country in supplying work for those unemployed who are not physically fit. Much of the digging, gardening, etc., was found unsuitable for skilled factory workers.

If the reports of the industrial conditions in New England are correct, any considerable concern regarding unemployment in this part of the country may soon be at an end but in the meantime it would be well if every water-works official would keep his superiors informed of the water-supply needs in his community, the profitableness of giving employment on necessary water-works construction, and the danger to the public health of a poorly maintained water-works plant.

The Engineering Societies of Boston, with which the New England Water Works Association is affiliated, has held many conferences with a view to establishing a board of engineers for advising unemployment committees and others concerning proposed construction activities for the relief of the unemployed. The New England Water Works Association could be of valuable assistance to that committee in its proposed activities.

RELIEF OF UNEMPLOYMENT AT LEOMINSTER BY WATER WORKS ACTIVITIES.

BY W. GUY CLASSON.*

[*Read March 9, 1932.*]

Almost every city and town in the state and probably in the country, was faced with more or less unemployment, during the last year and continues to be at the present time. In Leominster it seems to have been a case of more rather than less.

Early in the year Leominster was authorized by the Legislature to borrow $100 000 within 5 years for reservoir improvements. We had planned at that time to carry the work over a period of five years, but as so many people were out of work, it was decided to speed up this program and spend the money a little faster. A $25 000 bond issue was also obtained for 16-in. pipe lines, and with a small balance left from 1930, 6- and 8-in. pipe lines were also installed. Practically all of this work involved replacing small pipes with larger sizes.

As the Water Department had these funds available, it fell to its lot to take care of as many of the unemployed as possible. Men of many different national origins were employed, but those of French origin predominated. So-called Americans came next, then Irish, Italians and others. Many trades were represented. Among them carpenters, bricklayers, painters, machinists and general factory help. Not many of the men had used a pick and shovel before for any length of time.

At first 40 cents per hour was the minimum wage. Later this was reduced to 35 cents per hour.

As we increased our working force we had to have more foremen. These were recruited from regular water-works employees, at their regular wages. I must give them credit for doing good work.

We did not get a hundred cents on the dollar from the inexperienced men, and we had not expected it, but as a general thing we got a fair day's work. Of course, there were slackers and some that were not physically able to do the work. It was felt that whatever work we could get out of these men, however, was better than the dole system, and I believe the men were better satisfied. The men had to show some life after a week or ten days' trial, or they were replaced by others.

Not all of the money has been spent, the cost of the 1931 work being distributed as follows:

*Superintendent, Leominster Water Works, Leominster, Mass.

No Town Dike	$28 760.85
No Town Dam	2 701.39
Goodfellows Dam	4 623.30
Clearing stumps	4 742.40
Draining swamps	1 340.13
Venturi meter and chlorinators	4 700.39
Land	4 000.00
Total	$50,868.46

The total cost of laying 5 061 ft. of 16-in. and 4 738 ft. of 6- and 8-in. pipe was $36 999.42.

Since January 1, 1932 we have been at work draining swamps and building two diversion ditches; one is to take the drainage of a quarry away from the watershed, to prevent pollution of our reservoir; the other is a new channel to divert the main brook to our reservoir some 300 to 500 ft. east of the old location. This work has been done by our regular men and by some from the Community Chest.

Work around the reservoirs will continue during 1932, and we expect to replace some 4- and 6-in. pipe with larger sizes and to give employment to as many men as possible.

PROCEEDINGS.

February Meeting.

Hotel Brunswick, Boston, Mass.

Tuesday, February 9, 1932.

President George C. Brehm in the Chair.

The Secretary announced the election by the Executive Committee of the following to membership:

Member: Fred Townsend Coffin, Superintendent, Hudson Water Company, Hudson, N. H.

Associate: Perrin, Seamans & Co., Inc., Railroad, Mill and Contractors' Supplies, Boston.

The President called attention to two legislative bills of interest to water-works men in Massachusetts.

A paper "American and English Water Works Practice — Random Impressions of an English Chemist," was read by John T. Calvert, London, England; Commonwealth Fellow, Massachusetts Institute of Technology. This paper was discussed by E. Sherman Chase, Robert Spurr Weston, Gordon M. Fair, Arthur L. Shaw, Linn H. Enslow, and W. G. Classon.

A paper "Politics and the Water-Works Superintendent," was read by W. A. Hardenberg, Associate Editor, Public Works, New York, N. Y. This paper was discussed by President George C. Brehm, Roger W. Esty, E. Sherman Chase, Warren J. Scott, Herbert B. Crowell, Stephen H. Taylor, David A. Heffernan, Brenton W. Vaughan, Edward F. Hughes, Donald W. Foster, and Frank J. Gifford.

A motion empowering the President to appoint a committee to study the problem of tenure of office of water-works superintendents was presented and carried.

(*Adjourned.*)

March Meeting.

Hotel Brunswick, Boston, Mass.

Wednesday, March 9, 1932.

Vice President Richard H. Ellis in the Chair.

The Chairman announced the death of one member: Edwin H. Rogers.

The Secretary announced the election by the Executive Committee of the following new members:

Arthur B. Stiles, Superintendent, Owego, N. Y.; George N. Buckhout, Treasurer, Newport Water Corporation, Newport, R. I.; Harold E. Watson,

Chemist, Newport Water Corporation, Newport, R. I.; Donald C. Calderwood, Engineer, Pennichuck Water Works, Nashua, N. H.

A paper "Accounting for Water Districts," was read by James W. Graham, Treasurer and General Manager, Portland Water District, Portland, Me. Messrs. David E. Moulton, Henry T. Gidley, Donald C. Calderwood, Burton L. Winslow, Walter E. Moore, J. Walter Ackerman, Frank J. Gifford, Francis H. Kingsbury and Paul F. Howard took part in the discussion.

A paper on "Water Works Activities for Helping in Relief of Unemployment at Leominster," was read by W. Guy Classon, Superintendent Leominster Water Works, Leominster, Mass. Mr. Classon also showed several reels of moving pictures which were taken during the progress of the work.

Mr. David E. Moulton extended an invitation to the members of the Association to attend the meeting of the Maine Water Utilities Association on March 28, 1932.

(*Adjourned.*)

Special Spring Meeting.

Nashua Country Club, Nashua, N. H.

Wednesday, May 11, 1932.

President George C. Brehm in the Chair.

Address of Welcome by Hon. William F. Sullivan, Mayor of Nashua, Past President, New England Water Works Association, and President, Pennichuck Water Works, Nashua, N. H.

Mr. President, members of the Association and particularly the active old veterans:

I speak of the old veterans because I am now in that class myself and I see a goodly number here today.

It is a pleasure for me to extend to you the greetings of the City of Nashua and to welcome you here. It is true I am both Mayor of Nashua and President of the Pennichuck Water Works, a peculiar combination, that of excutive of a utility and of a city. It shows the good will and kindly spirit of our city. The fact that I happen to be associated with a utility is not held against me; that is as it should be.

Nashua is an old township but a young city, about 77 years old. Once it was part of Massachusetts, but Massachusetts parted with us or we with Massachusetts.

I am not going to take much time because I know you realize the sincerity of the welcome that Nashua extends to you. The New England Water Works Association has come to Nashua, the Gate City, which has neither gates nor locks, and particularly no bars.

"Water," the purest and best of all the things that God created. I

want to say to you that I have seen it glisten in tear drops on the sleeping lids of infancy; I have seen it trickle down the blushing cheeks of youth, and go in rushing torrents down the wrinkled cheeks of age. I have seen it in tiny dew drops on the blades of grass and leaves of trees, flashing like polished diamonds when the morning sun burst in resplendent glory o'er the eastern hills. I have seen it trickle down the mountain sides in tiny rivulets with the music of liquid silver striking on beds of polished diamonds. I have seen it in the rushing river rippling over pebbly bottoms, purling about jutting stones, roaring over precipitous falls in its mad rush to join the mighty father of waters, and in the mighty father of waters I have seen it go in slow and majestic sweep to join the ocean. And I have seen it in the mighty ocean on whose broad bosom float the battle fleets of all nations and the commerce of the world, but, gentlemen, I want to say to you now, that as a beverage it is a damn failure.

A paper "The Nashua Fire of May 4, 1930" was read by Mayor Sullivan.

A paper "Recent Remedial Measures for Control of Tastes and Odors Due to Development of Organisms in Spot Pond of the Boston Metropolitan Water Supply," was presented by Samuel E. Killam and discussed by Messrs. Joseph C. Knox, Charles E. Kendall and others.

Following Mr. Killam's paper there was a general discussion of difficulties encountered in collecting water bills during the depression. This discussion was participated in by Messrs. Roger W. Esty, Percy R. Sanders, Albert L. Sawyer, Leon A. Goodale, Frank J. Gifford, Stephen H. Taylor, William F. Sullivan and Henry T. Gidley.

A motion empowering the President to appoint a Nominating Committee was presented and carried.

A motion to extend a rising vote of thanks to Mayor Sullivan and the committee which arranged the Spring Meeting was proposed and carried.

(*Adjourned.*)

Water Works School.

In order to quicken the interest of water-works superintendents and water-plant operators in the sciences upon which water-works construction and operation are based, the New England Water Works Association with the coöperation of the staffs of the Departments of Sanitary Engineering of the Harvard Engineering School and of the Massachusetts Institute of Technology offered a short course in Water Works Operation during the week of June 6, 1932.

The course consisted of lectures, conferences, laboratory work and excursions and was offered with the approval of the State Departments of Health of New England.

No one but a water-works employee or a member of the Association was admitted to the course. Non-members were admitted upon application on their behalf by a water commission, department or company, or a State Department of Health.

The tuition fee for the course was $15, payable to the Association in advance. The Association suggested that water commissions, departments and companies pay the fees of employees who applied for admission.

The following men registered for the School and received certificates of attendance upon completion of the course:

Donald C. Calderwood	Nashua, N. H.
Arthur J Connolly	Malden, Mass.
Clarence R. Dion	Westerly, R. I.
Wm. B. Duffy	No. Andover, Mass.
Chas. W. Ellis, Jr.	Randolph, Vt.
Clarence B. French	Waltham, Mass.
Timothy W. Good	Cambridge, Mass.
Robt. F. Hancock	Lawrence, Mass.
Michael J. Herlihy	Newton, Mass.
Edward F. Hughes, Jr.	Watertown, Mass.
Arthur C. King	Taunton, Mass.
Wm. G. Lumbert	So. Scituate, Mass.
Howard C. Mandell	New Bedford, Mass.
C. E. Miller	Dedham, Mass.
Edward Morgan, Jr.	Hudson, Mass.
W. L. Newman	Dedham, Mass.
John H. Robinson	Concord, Mass.
Daniel Ryan	Brockton, Mass.
Dennis P. Sullivan	Malden, Mass.

The program of the School was as follows:

Monday, June 6.

At the Massachusetts Institute of Technology.

Morning Session: Introduction by R. S. Weston, Chairman of the Committee on a Water-Works School. Hydraulics. Professor Camp.

Afternoon Session: Pumps and Pump-testing. Professor Camp.

Tuesday, June 7.

At the Harvard Engineering School.

Morning Session: Population, Water Consumption and Hydrology. Professor Fair.

Afternoon Session: Development of Water Supplies. Professor Fair.

Wednesday, June 8.

At the Harvard Engineering School.

Morning Session: Water Chemistry. Professor Whipple.

Afternoon Session: Microscopy. Professor Whipple.

Thursday, June 9.

At the Massachusetts Institute of Technology.

Morning Session: Sanitary Science. Professor Horwood.

Afternoon Session: Water Bacteriology. Professor Horwood.

Friday, June 10.

At the Harvard Engineering School.

Morning Session: The Chemistry of Water Purification. Professor Whipple.

Afternoon Session: The Hydraulics of Water Purification. Professor Fair.

Evening Session at the Walker Memorial: Dinner with addresses by the President and Secretary of the Association and by the Hon. William F. Sullivan, Mayor of Nashua, N. H. Presentation of Certificates of Attendance and informal discussion of the School's accomplishments.

Saturday, June 11.

Visit to Cambridge Water Purification Plant. Professor Whipple.

(*Adjourned.*)

PROPOSED AMERICAN TENTATIVE STANDARD ON CEMENT-MORTAR LINING FOR CAST-IRON PIPE AND FITTINGS.

[*Received April 1, 1932.*]

FOREWORD.

The Sectional Committee on Specifications for Cast-Iron Pipe and Special Castings functions under the procedure of the American Standards Association and has as sponsors the American Water Works Association, the New England Water Works Association, the American Gas Association and the American Society for Testing Materials.

This Sectional Committee has prepared a proposed American Tentative Standard on Cement Mortar Lining for Cast-Iron Pipe and Fittings and in accordance with American Standards Association procedure has submitted this for preliminary approval to the four Sponsors. If and when these four bodies have approved the proposed specification, it will be submitted by them to the American Standards Association for approval as an American Tentative Standard.

So far, the draft specification has been approved by the American Gas Association. The American Water Works Association referred it to its Committee on Water Works Practice, which has recommended its approval.

On recommendation of the representatives of the N.E.W.W.A. on this Sectional Committee the proposed standard is printed herewith in the JOURNAL for the information of the membership and others interested and for the purpose of soliciting general comment and criticism.

This draft standard was prepared by Sub-Committee 3-C on Inorganic Coatings. The first chairman of this committee was James E. Gibson, Manager and Engineer of the Charleston, S. C., Water Department, who was chosen because of his pioneer work in the development and use of cement linings for cast-iron pipe in Charleston. On Mr. Gibson's resignation he was succeeded as chairman by E. O. Sweet, Superintendent of the Birmingham, Ala., Water Works Company, who completed the draft in its present form. The draft was then passed to the superior committee, Technical Committee No. 3 on Corrosion and Protective Coatings, the chairman of which is Leonard P. Wood, Designing Engineer, New York Board of Water Supply. After approval by Technical Committee No. 3 the draft was passed to the Sectional Committee and received its approval.

The use of cement mortar linings for cast-iron pipe has become common only within the last few years and the technique is changing and improving as time goes on. This will probably result in future changes in

this specification from time to time. The specification therefore purposely avoided too definite limitations. This fact has caused some questions to be raised and it is thought that the following explanation will be useful.

The thicknesses of lining were increased from previous practice because of a conviction that former thicknesses did not offer sufficient assurance of adequately covering irregularities in the surface of the iron and in the straightness and dimensions of the pipe and did not afford sufficient body of cement mortar to promise long life where the water was corrosive to calcium carbonate.

The thickness was not made greater because the specified thickness was the greatest that the manufacturers believed could be applied without excessive trouble with shrinkage, causing loose spots or cracking.

The specification was not made more definite with respect to proportions of mixture, kind of cement and sand analysis, because no agreement could be reached in the present state of the art as to what were the optimum conditions and because the thicker linings demanded by this specification were beyond the commercial practice of the various manufacturers and were expected to require considerable experimentation and variation of manufacturing technique in order to produce the best linings of the new thicknesses. Experiments already made showed that extra care was needed for thicker linings.

The centrifugal process of application was not specified, because it was felt that in the present state of the art the process should be left open to possible future developments.

In brief, the specification went as far as the state of a new art and the difficulties experienced by the manufacturers with thicker linings appeared to justify. It was frankly put out as a first step only toward a better specification with the expectation that the experience developed under it would furnish the ground work for further improvement.

The sub-committee on cement linings has in process at the Birmingham Water Works plant, where its chairman is Superintendent, some long-time tests on different kinds of cement linings, designed to show the effects of independent variation of type of cement (four types), proportion of sand, and thickness of lining. These linings are in pieces of 6-in. pipe and in 6-in. elbows exposed to running water of a relatively soft, corrosive quality. From these tests it is hoped to learn something both as to proper composition and necessary thickness of lining to insure permanency.

PROPOSED AMERICAN TENTATIVE STANDARD ON CEMENT-MORTAR LINING FOR CAST-IRON PIPE AND FITTINGS.

July 20, 1931

NOTE: *This Proposed Standard is Still Subject to Change on the Basis of Comments Received, Before it is Submitted to the American Standards Association for Approval.*

CEMENT.

1. The cement used for making cement mortar shall be Portland cement, complying in all respects with the standard specifications of the American Society for Testing Materials, Serial designation C-9-21.

SAND.

2. The sand for mortar shall consist of a clean, sharp, hard silicious sand, free from loam, clay, organic matter, or other foreign substance considered as deleterious for good mortar. The sand shall be well graded, and when tested by laboratory sieves, shall meet the following specifications:

Total passing 12 mesh sieve, 100 per cent.
Total passing 100 mesh sieve, not over 5 per cent.

CEMENT MORTAR.

3. The cement mortar used for lining pipe shall be a mixture of the above specified sand and cement in such proportions as to obtain a good, hard, dense lining, reasonably well bonded to the pipe, and with a smooth interior surface. (A mixture which has been found to give very satisfactory results consists of three parts cement to one part sand, by volume.)

4. The cement mortar shall be thoroughly mixed, only sufficient water being added to form a workable mixture for placing in the pipe.

5. Only sufficient cement mortar shall be mixed for the immediate requirements of lining.

6. The water for tempering the cement mortar shall be free from harmful amounts of oil, acid, alkali, organic or vegetable matter.

PREPARATION OF PIPE FOR LINING.

7. Pipe to be lined with cement mortar shall not be coated inside with tar or other asphaltum products. Its interior surface shall be thoroughly cleaned of all core sand, mud, grease, foreign materials, or any sharp projections of iron which might project through the lining. Pipe shall be tested hydrostatically before being lined.

Method of Applying the Cement Mortar Lining.

8. Sufficient cement mortar shall be introduced to produce the required thickness of lining and spread evenly over the interior surface of the pipe, by any suitable means. A careful examination shall be made after this operation is completed to see that the inner surface of the pipe is completely covered with cement mortar.

9. The shoulder of the bell and the end of the spigot may be covered with cement mortar by applying with a brush.

10. Surplus cement mortar shall be removed from the interior of the bell so as not to interfere with proper keying of the joint.

11. The work of lining the pipe shall be done in a building where the product shall be protected from the direct rays of the sun, and from extreme weather conditions, such as rain, frost, etc. The product shall not be put in the yard until the cement has set sufficiently to avoid injury or damage thereto.

12. Patching of improperly lined pipe will not be permitted.

Smoothness of Lining.

13. The lining of straight pipe shall be smooth and substantially free from noticeable ridges, corrugations, projections or depressions. The lining of fittings shall be as smooth as practicable.

Outside Surface of Pipe.

14. Unless otherwise specified, no coating shall be applied to the outside surface of cement-mortar-lined pipe and fittings.

Lining Fittings.

15. The interior surface of fittings shall be lined by applying cement mortar as specified in previous paragraphs, evenly and uniformly, and as nearly as practicable of the thicknesses specified for the corresponding sizes of pipe.

Thickness of Lining.

16. The minimum thickness of lining for the various size pipes shall be as follows:

Nominal Size of Pipe. Inches.	Minimum Thickness of Cement-Mortar Lining. Inches.
4	$\frac{1}{8}$
6	$\frac{1}{8}$
8	$\frac{1}{8}$
10	$\frac{1}{8}$
12	$\frac{1}{8}$
14	$\frac{3}{16}$
16	$\frac{3}{16}$
18	$\frac{3}{16}$
20	$\frac{3}{16}$
24	$\frac{3}{16}$

17. A plus tolerance of $\frac{1}{8}$-in. in thickness of lining shall be permitted on all size pipe from 4 to 24 in. No minus tolerance to be allowed.

18. Linings of greater thickness will be furnished when specified.

19. The thickness of lining may be determined by means of spear measurement, using a hardened steel point not greater than $\frac{1}{16}$ in. in diameter. The inspector shall pierce the lining immediately after is it placed in the pipe, and before cement has set, at four diametrically opposite points of the pipe at bell and spigot ends, making two sets of measurements at each end. The first set shall not be greater than 4 in. from the respective ends of the pipe and the second set shall be made as far into the interior of the pipe as can readily be obtained by reaching into the pipe without injuring the lining.

20. All measurements shall be within the limits as specified.

21. At the ends of the pipe where the lining naturally tends to taper off to a thin edge, the full thickness of lining shall extend to within one inch of end of pipe.

22. For linings of the above specified thickness, or of greater thickness, failure of the lining to completely adhere to the wall of the pipe shall not be cause for rejection, if the lining conforms to these specifications in all other respects (see Footnotes).

Curing Cement Mortar Lining.

23. Immediately after pipe is lined with cement mortar, it shall be protected in a suitable manner to prevent the too rapid withdrawal of moisture from the cement mortar, and if necessary, suitable means shall be provided to keep lining damp for a period of at least twenty-four hours after lining.

24. No pipe shall be shipped until the lining is thoroughly set.

Footnotes:

The above tentative specification provides for thicker cement linings than have generally been used in American practice. In view of the unavoidable irregularities in the inner surface of cast-iron pipe, of the known solvent action of many waters on the lime content of Portland cement, and the limited experience (only about seven years) with thin Portland cement linings in cast-iron pipe, thicker linings are believed to be desirable as a matter of insurance.

In the present state of the art such thicker linings are more prone, when dry, to a minute separation from the wall of the pipe; when wet, however, slightly separated cement linings swell into close contact with the pipe. The Committee believes that the thicker linings recommended will have longer life and will prevent tuberculation and maintain carrying capacity longer than thinner linings which may show somewhat less temporary separation from the pipe.

The Committee refrains from attempting, at this time, to specify the amount, or area, of the non-adherence of the lining which shall cause rejection. It is realized that the manufacturer will produce the best pipe he can and that it may require some little experimentation on each size and thickness of lining to secure the best adherence. The judgment and common sense of the inspector and of the manufacturer's forces are relied upon to secure the best practicable results during this period of development, rather than an arbitrary limit to the permissible area of non-adherence.

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CONTRACTORS

G. FERULLO COMPANY
General Contractors
Specializing in Water Works
31 NORTH SQUARE
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Telephone, Richmond 1200

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Public and Private Water Supply
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ANTHONY ROSS & SON
Public Works Contractors
(Since 1890)
Trailer Service Trench Excavators
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They Didn't Buy 1,500,000 Water Meters Just for Fun

In the last 40 years we have sold over 1,500,000 Hersey Meters to many water departments who had just one idea in mind . . . to save money! They could have purchased cheaper meters. But they could not have purchased cheaper service. And that is where you make your savings . . . in cheaper service.

Economize where it is safe to economize.

Buying low-quality meters for the sake of a low purchase price is not economy.

The original cost is only a small part of the expense. Mounting upkeep makes an unreliable water meter an increasing burden . . . a growing source of waste and extravagance.

It's good business for you to buy low-cost service. It's good business for us to supply it. So, in a day when so many commodities are being produced and sold on a "price" basis . . .

We shall continue to put highest quality material and workmanship into Hersey Water Meters.

Hersey Quality is Real Economy

HERSEY
WATER METERS

HERSEY MANUFACTURING COMPANY

Main Office and Works: **Corner E and 2nd Streets · South Boston · Massachusetts**

NEW YORK CITY, 290 Broadway; PORTLAND, ORE., 475 Hoyt Street; PHILADELPHIA, PA., 314 Commercial Trust Bldg.; ATLANTA, GA., 510 Haas-Howell Building; DALLAS, TEX., 402 Praetorian Building; CHICAGO, ILL., 844 Rush Street; SAN FRANCISCO, CAL., 553 Howard Street; LOS ANGELES, CAL., 450 East Third Street

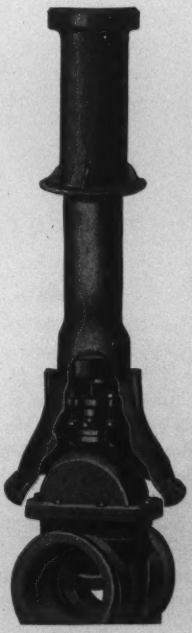
BINGHAM & TAYLOR'S Sliding Type Service and Valve Boxes are meeting with the approval of many New England Waterworks officials.

The cuts shown are our two and three piece sliding type adjustable valve boxes.

The flange on the bottom of the top section can be located any distance from the top.

We carry a complete stock on hand at all times.

Wire, phone or write us when you are in a hurry for a shipment.



ESTABLISHED 1849

Bingham and Taylor Corporation

MANUFACTURERS

575-601 Howard Street . . Buffalo, N. Y.

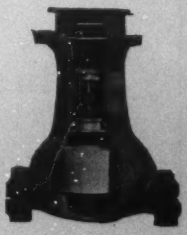
A little sermon on TRIDENT METER INTERCHANGEABILITY

You wouldn't dump your water meters *in the ash can!*

Of course not! Yet old water meters whose basic design has been radically changed or "improved" must go into the discard, or you lose money. Meter replacement, and storing great numbers of spare parts for many *different* types of meters COSTS MONEY. But on the other hand . . . . when you have installed Interchangeable Trident Water Meters (even if they were put in A GENERATION AGO) you simply replace old style parts with the new, improved UNIT PARTS for the SAME TYPE TRIDENT METER, at a fraction of the cost. No Trident Meter need EVER be replaced. The type never becomes obsolete. The newest oil-enclosed gear train, or register, or disc chamber, fits the old TRIDENT casing. Lambert Meters are also interchangeable.

Pioneers in Meter Progress . . . . Yesterday, TODAY, Tomorrow

TODAY'S improved New Unit Parts inserted in casing of TRIDENT METER No. 50908 delivered March 10, 1899.



NEPTUNE METER COMPANY
THOMSON METER CORPORATION
50 East 42nd Street : : New York City
Neptune Meter Co., Ltd., Toronto, Canada

trident

LAMBERT Water Meters are interchangeable, too

ARCTIC
Don't be Fooled by Appearances.
Water Meters may look alike but under the surface there is a vast difference in quality.
Take a Pittsburgh Water Meter apart . . . . see for yourself the HIDDEN QUALITIES. Then put it to the most severe tests you know. You will find the results bear out all that we have said about them.
Forty years of water meter manufacture has built up a reputation that must be maintained.
PITTSBURGH EQUITABLE METER COMPANY
Main Offices and Factories—Pittsburgh, Pa.
New York
Chicago
Seattle
Dallas
Salt Lake City
Tulsa
Kansas City
Columbia
Los Angeles
Houston
Davenport
TROPIC

When tax-payers ask questions-

Ludlow users have the answer

Economy? **A cost of less than 2¢ per unit per year for repair parts on 8,000,000 Ludlow Valves and Hydrants in 3,000 cities and towns establishes new and necessary standards of maintenance economy.**

Foresight? **Acclaimed "the finest contribution in twenty years." The new Ludlow Diamond, already adopted by scores of cities and towns offers hydrant design for 1932 installations that will still be modern for years to come.**

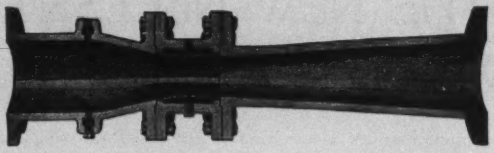
Efficiency? **Only the Ludlow Diamond Hydrant offers so many important advantages—self-illumination—ground line coupling flange—improved non-flooding valve—precision manufacture—lasting economy.**

Whether for new installation or replacement, the Ludlow Diamond is the hydrant that meets 1932 needs—that answers in advance tax-payers' questions—that sets a new standard for the cities of today and tomorrow. Write today for illustrated free folder.

The LUDLOW VALVE MFG. CO.

TROY · · · NEW YORK

1866 First with the Gate Valve · · 1931 The new Multi-Valve



The Venturi Tube

In 1891 the Venturi Tube was new. Those Engineers who knew of it hoped it would help solve the difficult problem of measuring the flow of water in large pipe lines.

In 1932 the Venturi Tube is accepted by Engineers as the most dependable and accurate means of measuring flow through pipe lines.

It may be worthwhile, however, to summarize a few of the important advantages of the Venturi Tube:

1. The flow is guided at all points.
2. The inlet and throat pressures are taken off at definitely fixed points; the annular pressure chambers assure the use of true average pressures.
3. The Venturi throat is accurately centered in relation to the rest of the pipe line.
4. The friction loss through a Venturi Tube is the lowest of any differential producer. The Venturi Meter, then, operates on a greater differential with less friction loss, and is a more powerful instrument with a wider measuring range than other meters.
5. The coefficients of the Venturi Tube have been definitely established in numerous calibration tests of tubes ranging in size from 1 inch to 8 feet in diameter.

VENTURI
"VENTURI" Registered

BUILDERS IRON FOUNDRY

"Builders of the Venturi since 1891"

9 Codding Street Providence, R. I.

THE NEW NECESSITY *for* WATER METER QUALITY

With municipal tax rates rising and revenue all pledged to meet other needs, the least that the city waterworks should do is to be self-supporting. This not only requires water meters, but the most accurate meters.

Full revenue must be earned from every meter if waterworks budgets are to balance or show a profit. The small leaks and wastes that once were overlooked, must be stopped. Uncompromising accuracy must be demanded. Yet initial cost must be kept within reason.

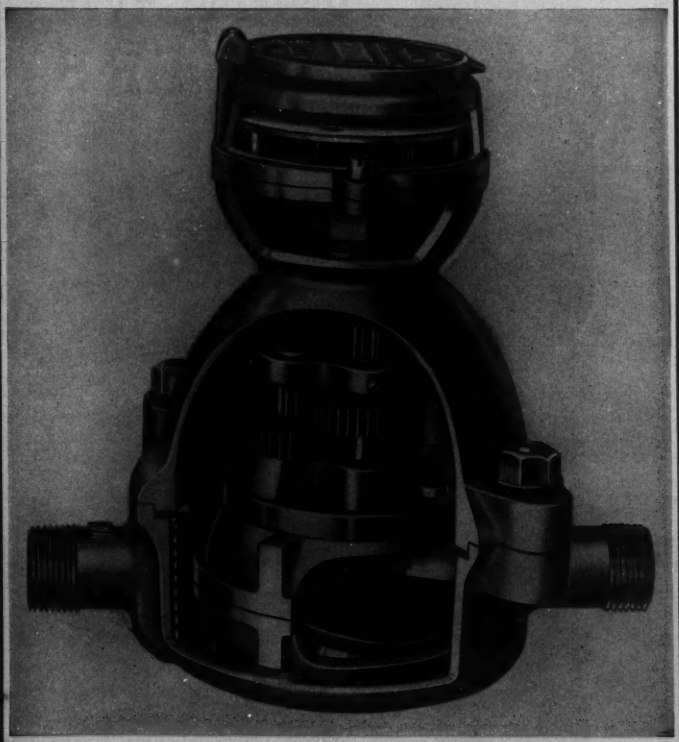
American and Niagara Water Meters meet both requirements by having the simplest design of any meters made, combined with the finest grade of materials and precision machining. They have extreme accuracy and maintain it with less friction, less wear. And still the cost is moderate because complicated construction is avoided.

Write today for further information on the economy of American and Niagara Meters.

Buffalo Meter Company
2896 Main Street
Buffalo, New York

NIAGARA *and* AMERICAN
IRON CASE BRONZE CASE
Water Meters

KING B B METER



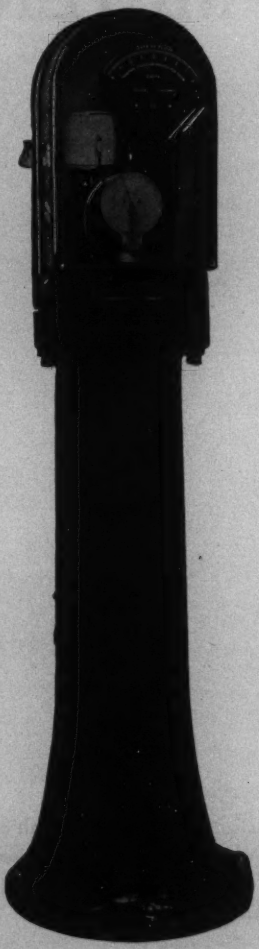
Direct outlet type. Open or oil enclosed gear train. With or without frost relief. A notable advance in meter construction.

UNION WATER METER CO., Worcester, Mass.

INCORPORATED 1868

WATER METERS
CHRONOMETER VALVES

EASY TURNING STOPS
PRESSURE REGULATORS



SIMPLEX
VENTURI TYPE
METERS

Indicate the flow on a uniformly graduated dial.

Record the flow on a rectangular chart with uniform graduations.

Totalize the flow on a five-dial totalizer, so designed that the last figure can be read with accuracy on a much larger scale.

They may be furnished for floor stand, wall bracket or panel mounting.

May be used for pump discharge — gravity supply — in the Filter Plant — or Sewage Treatment Works.

Simplex Meter Registers may be checked at any time while in service by use of apparatus furnished as standard equipment — an exclusive feature of the Simplex Meter.

Simplex Meters are the choice of many who value quality and accuracy above initial cost.

Write for data.

Simplex Valve and Meter Co.

6757 Upland St., Philadelphia, Pa.

"WATCH DOG" WATER METERS

ACCURATE *DURABLE*

DISC, CURRENT AND COMPOUND TYPES

Inquiries Solicited

GAMON METER COMPANY

NEWARK NEW JERSEY

METERS

The Kind You Want—As Many As You Want—When You Want Them

Six distinct types. All wanted sizes. Highest quality. All backed by a meter making experience of over sixty years. Remember the names:— **Empire, Nash, Crown, Gem, Empire-Compound and Premier.**

Especially remember the **Empire** (illustrated), the famous Oscillating Piston meter, which measures more accurately, is longer lived and lower in upkeep cost than any other.

Send postal for our meter literature.

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299 Broadway, New York

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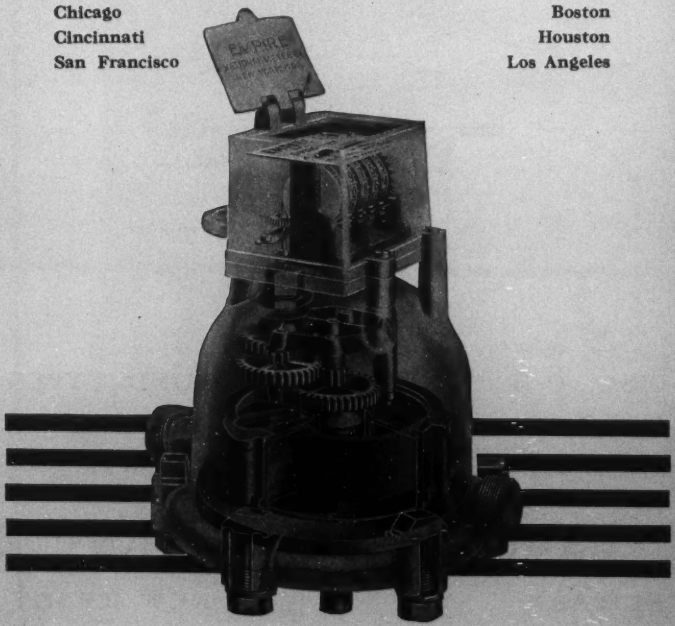
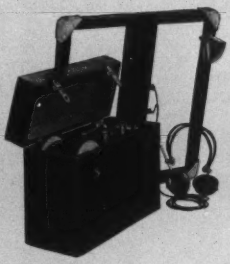
Cincinnati **Houston**
San Francisco **Los Angeles**



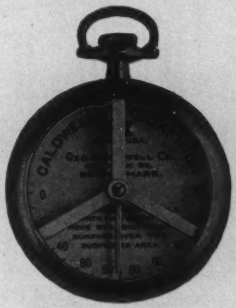
DON'T DIG

"PIPEFINDR"



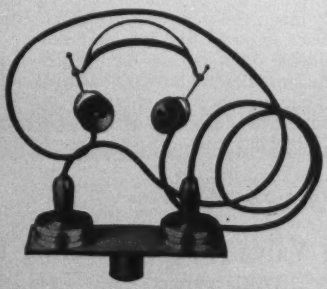
Actually TELLS you
Where IT is and
How DEEP it is

"BOXFINDR"



DURABLE
DEPENDABLE

"LEAKFINDR"



MOST Satisfactory of
any on the Market

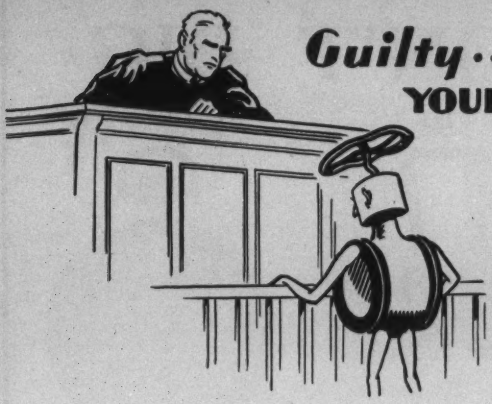
AQUAPHONE

INDISPENSABLE.

Catalog and Prices on Request

GEORGE A. CALDWELL CO.

MATTAPAN SQUARE BOSTON, MASS.



Guilty.. YOUR HONOR

ARRAIGNED before the bar of American industry, cheap products are quickly convicted of excessive maintenance expense, wasteful operation and costly replacement. Arguments of low first cost are thrown out by any judge with practical experience in cutting operating costs and pruning the maintenance budget.

Losses from inferior and inefficient valves might very easily mean the difference between red and black ink in the profit and loss statement. Let Darling Valves demonstrate their superior performance economies under your critical supervision. They are built to perform positively under the most exacting and extreme conditions — that is why they cost a little more.

The complete Darling line is pictured in the catalog. Write for it.

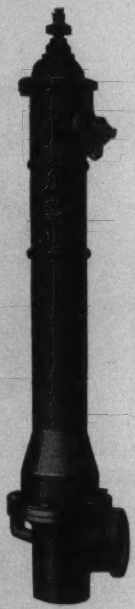
Darling Valve & Manufacturing Co.

Williamsport, Pa.

New York **Oklahoma City** **Houston**

DARLING

GATE VALVES



Type of Eddy Hydrant Popularly Used

More Than Sixty Years of Experience Goes Into All

EDDY

Hydrants and Valves

BUILT TO MEET EVERY EXACTING REQUIREMENT OF WATER-WORKS SERVICE

Practical water-works men instantly recognize the superior features of Eddy products. For instance, with the hydrant.

A damaged valve can be replaced in a few minutes — Water hammer is avoided by the valve closing against the pressure and the use of the cut-off under the valve, which gradually closes it —
Stems cannot be bent in closing the hydrant.
Nothing can lodge on the valve seat to prevent closing of the valve —
The Drip Rod can be removed without interfering with the hydrant in any manner —
The position of the stem of the hydrant indicates accurately the position of the valve —
Whatever can pass the valve opening will pass the standpipe —
No frost case necessary —
All of these points are explained thoroughly in our catalogue, which will pay you to study.

The Eddy Valve, Too

Has its distinctive and individual features. The double disk gates are free to adjust themselves in different positions every time the valve is closed, thereby keeping smooth and tight faces. And two bronze hooks on the ball loosely engage with the gates to prevent them from spreading at the top. The center bearing gates are forced to their seats with equal pressure at all points. There is a good deal more worth knowing about Eddy Valves. Further details will be sent for the asking.

Other Eddy Products

The Eddy line of water-works products also includes horizontal and vertical check valves, foot valves, hydraulically operated valves, indicator posts, etc.
All goods made by the Eddy Valve Company are manufactured exclusively at Waterford, New York.

WRITE FOR CATALOGUE

EDDY VALVE COMPANY

WATERFORD, N. Y., U. S. A.

It Pays to Specify . . . .

"MINERALEAD"

For Jointing Bell and Spigot Water Mains

PERFECT JOINTS

Complete at one pouring

INGOT FORM

Impervious to moisture
Convenient to handle
Eliminates waste

New England Distributor
FRED A. HOUDLETTE & SON, INC.
40 Central Street
Boston, Mass.

The Atlas Mineral Products Co.
OF PENNSYLVANIA
Mertztown, Pennsylvania
Established 1892

Developed and manufactured by the originators of G-K Sewer Joint Compound

CLEAN PIPE LINES

having high coefficients deliver more water and give better fire protection than corroded mains.

High coefficients mean greater delivery in gravity mains and lower power costs in pumping mains.

GENERAL PIPE CLEANING COMPANY

Commercial Trust Bldg. Philadelphia, Pa.

F. A. MAZZUR CO., INC.

ENGINEERS AND CONTRACTORS

WATER PUMPING INSTALLATIONS
SEWAGE PUMPING INSTALLATIONS
PUMPING STATIONS
POWER PLANT EQUIPMENT
SUCTION AND FORCE MAINS
TRANSMISSION LINES
SUBMERGED SUCTION LINES
DRIVEN WELL SYSTEMS

Emergency Work a Specialty

All Types of Pumps in Stock for Rental

141 MILK STREET Phone HANcock 4570 BOSTON, MASS.

RIGID INSPECTIONS AT EVERY STEP.

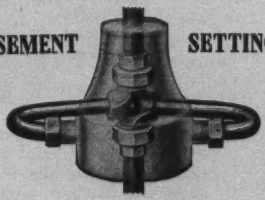
SMITH Gate Valves are rigidly inspected at every step in their manufacture. Everything humanly possible to insure their detailed perfection is done.

They have few working parts and those are non-corrodible. They will operate in any position. Their stems have a tensile strength of 60,000 lbs. per sq. in. All their bolts are hot galvanized.

SMITH
WATER WORKS SPECIALTIES & SUPPLIES

THE A.P. SMITH MFG. CO. *East Orange, N.J.*

The
COPPERHORN
METER COUPLING
for
BASEMENT SETTINGS



●1 **Meter set horizontally** at desired height in vertical pipe without ells, nipples or couplings.

●2 **All copper water way.** No rusting or corrosion. Freezing will not burst it.

●3 **Smooth oversize tubing** and sweeping bends, maximum flow.

●4 **Meter changes** do not disturb piping whether the meter is in or out.

●5 **On new services** it serves as a spacer to connect in the piping.

●6 **Provides a permanent** electrical ground connection.

May We Give You Further Information About the Copperhorn?

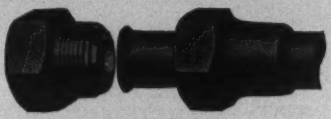
The FORD METER BOX COMPANY
Wabash, Indiana

The Hays Copper Plumbing Method

Regular Corporation Stop

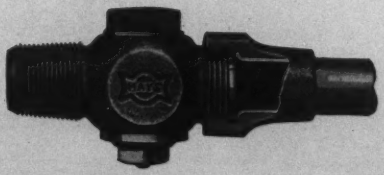
Adapter

In making an installation with Hays Copper Service Fittings the regular Corporation Stops can be used in conjunction with the adapter. It is not necessary to procure new mandrels, as the Corporation Stops are inserted with the regular mandrels, in the usual manner, after which the adapter is attached.



Open View of Adapter

These adapters are made with Female Thread for Increased I. P., Water Works Standard or Lead Flange.

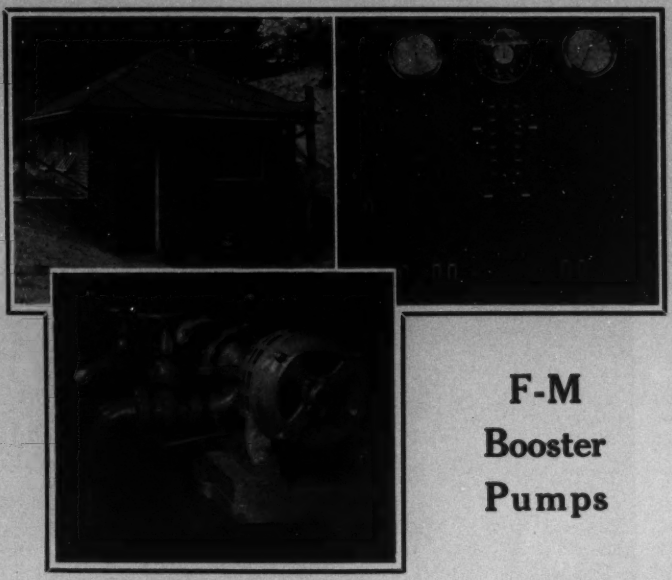


To use standard Corporation Stops with Increased I. P. or Water Works Standard Thread, and where a direct connection of the Corporation Stop and Copper Pipe is desired, the above stop has been designed. (See cut above for sectional view of joint.) These stops permit a Hays 90° seal with the use of regular male mandrels.

Write for complete details of

The Hays Copper Plumbing Method for Water Works and House Plumbing

Hays Manufacturing Co. Erie, Pa.



F-M Booster Pumps

At SOUTH HADLEY, MASS.

Shown above are the exterior of the South Hadley Water Works Pumping Station, the two F-M Motor Driven Centrifugal Pumps installed in the station and the control equipment. The station is located at one extreme end of the town and takes water from a small reservoir under a positive head of approximately 12 or 15 feet and pumps it through the main section of the town to a standpipe at the other end. Both pumps and motors are of ball bearing design, which construction was selected because of the desirable feature of lubrication. The bearings require attention only once a year.

FAIRBANKS, MORSE & CO.

88 High Street, Boston

FAIRBANKS-MORSE

PUMPS · DIESEL ENGINES · MOTORS

DE LAVAL

Steam Turbine Driven Centrifugal Pumps with Condensing Equipment

Millis, Mass.

A SMALL highly efficient DE LAVAL turbine driven centrifugal waterworks pump complete with centrifugal injection pump and multi jet type condenser replacing obsolete reciprocating steam pump.

Capacity per day - - - - -	750,000 Gallons
Head - - - - - - - - -	190 Feet
Steam Pressure - - - - -	80 lb. Gauge
Exhaust - - - - - - - -	28″ Vacuum

Complete Installation by

TURBINE EQUIPMENT COMPANY

OF NEW ENGLAND

80 Federal Street Phone LIB erty 5993-4 Boston, Mass.

New England Representatives for

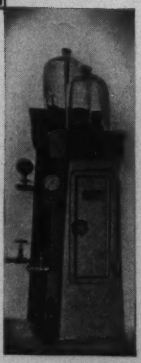
DE LAVAL STEAM TURBINE CO., TRENTON, N. J.

Throbbing giants of power—slicked and groomed by men whose eyes and ears instinctively respond to the first trace of failure.

(A Bourke-White Photo)

So long as pure water courses its way to waiting millions, just so long must men be sure that chlorination neither falters nor fails.

The Eight-hour Shift knows
DEPENDABLE CHLORINATION



BLUEPRINTS reveal the simplicity of W & T Vacuum Chlorinators . . . the freedom from troublesome mechanical parts . . . the rugged construction . . . But for an honest opinion of its dependability, how it stands up in service, go to "the man on the shift". Eight hours a day he observes it, checks its accuracy, appreciates its unfailing performance . . . and best of all, knows how little it costs for maintenance.

You need only install W & T Vacuum Chlorinators to secure Dependable Chlorination. Ask for Technical Publication No. 38.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus

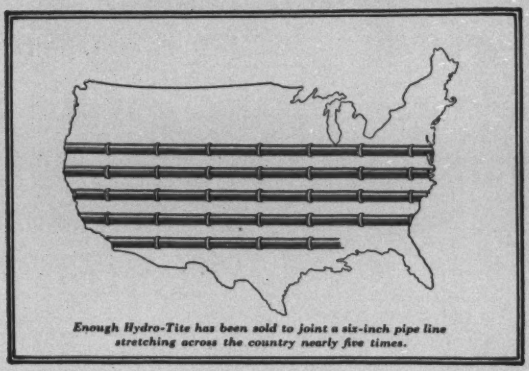
NEWARK, NEW JERSEY — Branches in Principal Cities

"The only safe water is a Sterilized Water"

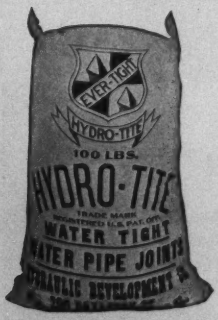
SA-38

HYDRO-TITE

— *its record . . .*



Enough Hydro-Tite has been sold to joint a six-inch pipe line stretching across the country nearly five times.



HYDRO-TITE is always the same, comes in moisture proof, non-dusting bags, is shipped the day order is received. Every bag is subject to a guarantee which makes it impossible for you to lose by trying this modern pipe jointing material.

. . . over 21 years without a failure

Millions of joints in cast iron bell and spigot water pipe have been made with HYDRO-TITE.

In over 21 years not a single failure has been reported to us.

No wonder that year by year more waterworks men specify and use HYDRO-TITE and HYDRO-TITE equipment. They profit because HYDRO-TITE joints never blow out, leak 75% to 95% less than engineers specify for lead joints, withstand deflection and vibration, save 75% as compared with lead, require no caulking.

Write for HYDRO-TITE *data book*

Hydraulic Development Corporation

Main Sales Office:
50 Church Street, New York, N. Y.

General Offices and Works:
80 Boylston Street, Boston, Mass.

EVER-TIGHT
HYDRO-TITE

HYDRO-TITE

TODAY'S SELF-CAULKING WATER-PIPE JOINTING COMPOUND

8237

Main's Hotcoating for the inside of standpipes and water tanks, will stop all pitting and corroding, and is guaranteed for seven years.

Also

Main's Coverall Salt Air Paint, for the outside of standpipes and water tanks, guaranteed for four years.

M. B. MAIN **Box 189, Somers Point, N. J.**

STARKWEATHER ENGINEERING CO.

INCORPORATED

Engineers and Contractors for
Water Works and Sewage Pumping Plants

79 MILK STREET, BOSTON HANcock 4530

The "COREY" Hydrant

Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

Can be lengthened without shutting off water.

Will not flood if broken.

Positive Drip — cannot freeze.

Standpipe can be revolved quarter turns — Nozzles always in right direction.

Write for copy of our new Catalog "G."

CHARLES L. BROWN,
New England Sales Manager, Lock Box 2, Northboro, Mass.

RENSSELAER VALVE COMPANY
TROY, N. Y.

DONALDSON IRON CO.

MANUFACTURERS
...OF...

CAST IRON PIPE

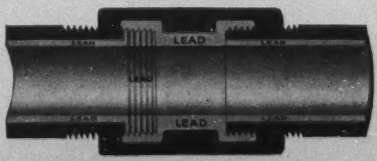
...AND...

Special Castings for Water and Gas.
Also Flange Pipe and Fittings.

Boston Office:
CHARLES F. GLAVIN
24 Milk Street

EMAUS,
LEHIGH COUNTY, PA.

This shows Pipe just entering Lead Threads of Fitting



This shows Pipe Screwed into Lead Threads and Shoulder of Fittings

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Galvanized Lead Lined Iron Pipe and Fittings

Low Cost — Easily Installed — Permanent *Inquiries respectfully solicited*

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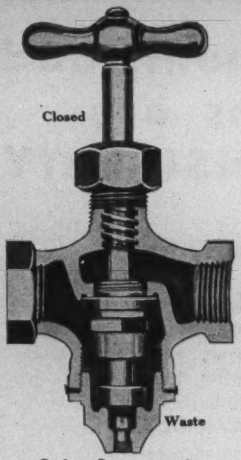
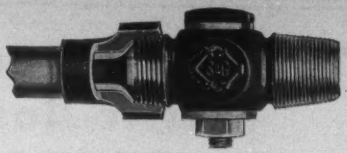


Gorham Compression Stop and Waste Cock



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We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the adaptability of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves":
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Sizes to 24 in.

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4. Operates quickly or slowly as required — No attention necessary.
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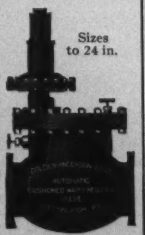

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Operated by protected enclosed copper float.

Cushioned by both air and water.

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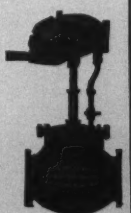

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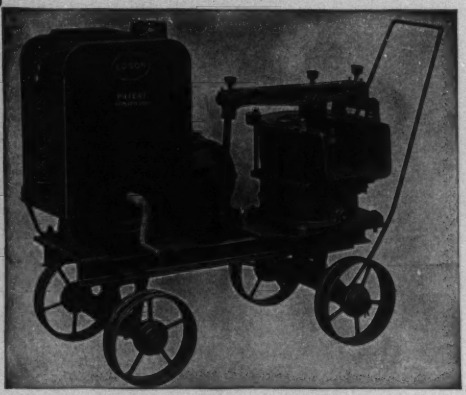

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